RIBEYE AREA AS AN INDICATOR OF MUSCLING IN BEEF CATTLE

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1991

ACKNOWLEDGEMENTS

I would like to express sincere gratitude to Dr. Roger West, chairman, and Dr. Dwain Johnson, Dr. Don Hargrove, and Dr. Ramon Littell, members of my supervisory committee, for their guidance and assistance throughout my graduate program and in the preparation of this manuscript.

I also extend appreciation to Dr. Fred Leak, Dr. Tim Marshall, Dr. Saundra TenBroeck, Dr. David Prichard and Mr. Don Wakeman for their assistance, suggestions, and friendship during my graduate program.

There are numerous people who assisted in all phases of my graduate program: Mr. Larry Eubanks and the crew of the Meat Laboratory; Jerry Wasdin and the crew at the Pine Acres Research Unit; Janet Eastridge, Debbie Neubauer, and Ana Zometa of the Meat Science Laboratory; and Mary Beth Forte, secretary. My sincere thanks goes out to these individuals for their extensive assistance in data collection and preparation.

Special thanks are expressed to fellow graduate students too numerous to mention individually--you know who you are! I am indebted for your friendship, support, and assistance throughout my five years at the University of Florida. I will always have many fond memories of UF because of you.

I am sincerely grateful to my parents, JoAnn and Dale, who were the most influential forces in my pursuit of this degree. I probably would have stopped short of this degree if it weren't for them. For that encouragement and support I will be forever endebted. I am also thankful to my two very supportive sisters, Shari and Emily, and my brother-in-law Dennis.

Finally, I express my deepest gratitude to Laura, my wife, for believing in me and not giving up.

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December, 1991

Chairperson: Roger L. West
Major Department: Animal Science

This study was undertaken to assess the usefulness of ribeye area (REA) as a measurement of muscularity in beef cattle and to monitor growth of REA over time. The first study utilized 54 steers selected to represent six, 22 kg carcass weight ranges and three REA ranges. Cutability end points were defined as retail yield at 2.54, .64, and 0 cm fat trim, muscle/bone ratio, fat-free muscle/bone ratio, and separable lean. Significant correlations existed between REA and carcass cutability. REA alone explained from 12% to 20% of the variation in cutability. REA, plus the other yield grade variables, explained from 28% to 38% of the variation in carcass cutability, depending on the cutability end point. Although not different ($P>.05$), carcasses classified as "average," "above average," or "below average" for REA did show a trend for "above average" carcasses to have greater cutability than "below average" carcasses. In stepwise regression with other

carcass measurements and some individual muscle and bone weights, REA was included in all equations predicting cutability (R^2=.53 to R^2=.65). Part two of this study provided a look at cattle growth from a very young age to slaughter. Serial measurements of weight, ultrasound REA and fat thickness, and REA / 45.4 kg of live weight (REACWT) were regressed on age, and growth coefficients were evaluated. This study suggested that when evaluating growth preweaning, cattle of different sex condition should be evaluated separately. Frame size played a role in preweaning growth, as larger framed cattle had faster weight gain and REA growth than small frame cattle; however, REACWT was not different among frame sizes. Cattle of predominantly Angus breeding (80% to 100%) had slower ($P<.05$) weight gain and REA growth to weaning than did breed groups comprised of 20% to 100% Brahman breeding. Breed groups were not different ($P>.05$) for REACWT. This suggests that for evaluating REA in cattle up to weaning, REACWT may be a valid variable to utilize across frame sizes and breed groups. Postweaning, REA growth was not different among frame sizes or breed groups. In conclusion, REA is moderately associated with cutability, and REA on a relative live weight basis is the best method to assess REA growth.

CHAPTER 1
INTRODUCTION

Animals of all species vary considerably in composition as a result of their stage of growth, nutritional history, and genetic base (Topel and Kauffman, 1988). This variation in carcass composition provides a challenge for animal scientists and livestock producers to identify those animals which will produce the most "optimum" carcass composition. But how is "optimum" composition defined? Traditionally, the U.S. beef industry has relied on a strong market for high quality (high fat) beef, and this has helped to define "optimum" carcass composition. During the last decade, the link between diet, maintenance of health and the development of chronic disease has become increasingly questioned. Advice from national health organizations has influenced consumers to modify their diets by decreasing consumption of excess calories, fat, saturated fatty acids, and cholesterol (Call, 1988). Consumers became more health conscious and promptly demanded leaner meat products, thus modifying the definition of "optimum" carcass composition. In addition to consumer demands for more healthful meat products, the 1990s appear to be the decade of environmental awareness, where the industry will be forced to improve efficiency and eliminate unnecessary waste. Although this is not a major concern to the livestock and meat industry yet,

animal agriculture will eventually feel pressure from concerned consumers and will have to respond by producing animals more economically and more efficiently than ever before. Many management practices influence the efficiency of animal growth and there is much room for improvement. Currently, the beef industry produces more than 5 billion pounds of waste fat trim annually (Byers et al., 1988). To address this wastefulness and to become more economically efficient, the industry may again be forced to redefine "optimum" carcass composition.

May (1985) reported that from 1980 to 1984 the percentage of USDA Yield Grade 1 and 2 beef carcasses increased (30.6% to 45.3%), while the percentage of USDA Yield Grade 3, 4, and 5 beef carcasses decreased (69.4% to 54.6%). This trend probably continued through the late 1980s as well. Topel (1986) projected that the ideal carcass in the year 2000 will have the following characteristics: weight, 320 kg; age, 20 mo; muscle percentage, 73; ribeye area, 97 cm^2; fat thickness at the 12^{th} rib, .25 cm; percentage kidney pelvic and heart fat, 1; and marbling score, practically devoid. Some meat scientists may disagree with these predictions; however, changes must occur or the livestock and meat industry will eventually lose market share to competing protein sources. Current trends and predictions emphasize the need for accurate and precise methods to identify animal and carcass composition, so that the ever-changing definition of "optimum" carcass composition will be better understood. Because carcass composition continues to be an area of interest, so too do the methods used to determine composition. The most accurate method of determining carcass composition

would be to conduct a chemical analysis of the whole carcass (Hankins and Howe, 1946). Obviously this method has many drawbacks and is not applicable to an industry situation. Consequently, much research has been done to develop simplified techniques that are accurate and reliable across large groups of animals and that can be applied to industry situations. Many techniques have been described which involve chemical analysis of part of the carcass, which render them impractical for today's high-speed beef slaughter plants (Griffin et al., 1989). Therefore, methods that can predict carcass composition without destroying the carcass have been widely studied. One such technique was adopted in 1965 by USDA and is currently the basis for USDA Yield Grades for Beef. This technique was developed by Murphey et al. (1960) and was designed to predict the percentage of boneless retail cuts from the round, loin, rib, and chuck from 162 carcasses using the following equation: % boneless retail cuts = 51.34 - 5.78 (fat thickness, in.) - .462 (% kidney, pelvic, and heart fat) - .0093 (carcass weight, lb) + .74 (ribeye area, sq. in.). The simple correlation coefficient between the actual and the predicted yields were highly significant (r = .91). This original equation has been modified slightly (USDA, 1965) and has been reevaluated by many other researchers (Abraham et al., 1968; Brackelsberg and Willham, 1968; Cross et al., 1973; Powell and Huffman, 1973; Abraham et al., 1980). All of these researchers found the factors utilized in the USDA Yield Grade equation to be useful predictors of carcass composition; however, numerous published reports dispute the usefulness of ribeye area in equations that predict cutability. Cole et

al. (1960) found that ribeye area only accounted for 18% of the variation in separable carcass lean and that carcass weight alone was more useful in predicting separable carcass lean than the multiple regression including both carcass weight and ribeye area. Ramsey and coworkers (1962) found that when ribeye area was omitted from yield grade calculations, the resulting yield grades were more closely related to separable lean and fat than when ribeye area was included. Other researchers have also concluded that ribeye area should not be utilized in the yield grade equation (Epley et al., 1970). Despite this discrepancy in the literature, ribeye area remains in the USDA Yield Grade equation and is the only direct measurement of carcass muscling.

Research is being conducted on instrument grading of carcasses and ribeye area is considered one of the variables that should be studied (NCA, 1990). Also, beef cattle breed associations are currently collecting data to determine expected progeny differences (EPDs) for carcass traits, and ribeye area is one of the traits of interest (Cundiff, 1991). Real-time ultrasound will play an important role in both instrument grading and carcass EPDs. Topel and Kauffman (1988) report that recent developments in ultrasound technology have led to new interest in developing ultrasound techniques to predict carcass composition. Stouffer et al. (1959) first reported on the use of ultrasound for measurement of carcass traits. Since that time there has been a proliferation of new equipment and improved techniques. Campbell and Herve (1971) found that ultrasonically determined cross-sectional area measurements of the longissimus in the lumbar region can be

used to predict total muscle in live beef steers as accurately as prediction methods based on measurements of anatomical dissection. Kempster and Owen (1981) reported high correlations between ultrasonic measurements of cattle and carcass composition using several different types of ultrasound units. Simm (1983) conducted an exhaustive review of the literature concerning the use of ultrasound to predict carcass composition. In general, he found that ultrasonically measured muscle areas are the best predictors of dressing percentage, lean:bone ratio, and weight of retail cuts, while ultrasonic fat measurements are the best predictors of lean and fat percentages of the carcass. Stouffer et al. (1961) reported that operator proficiency was crucial for obtaining reliable ultrasound estimates. Simm (1983) also found operator proficiency was important in obtaining accurate estimates. Simm (1983) concluded that marked improvements in the accuracy of ultrasound were unlikely, since correlations between ultrasonic measurements and carcass composition are often as high as correlations between actual measurements of the carcass and carcass composition. Although improvements in ultrasound equipment have occurred since the publication of that review in 1983, no literature has addressed how those improvements may have increased the accuracy and/or precision of ultrasonic measurements for predicting carcass composition.

Several studies using more sophisticated ultrasound units have been published in recent years. Bailey et al. (1986) studied the relationship of ultrasonic estimates to carcass composition and muscle distribution and concluded

that for young, Holstein-type bulls that were of similar weight, the accuracy was too low to justify the commercial use of ultrasonic scans and linear body measurements. Miller et al. (1988) reported that ultrasound measurements of fat and ribeye area may be used to predict percentage carcass fat with reliable precision and accuracy (R^2 = .83, rsd = 2.61). Faulkner et al. (1990) reported on the usefulness of ultrasound 12^{th} rib fat thickness for prediction of cow composition. They found real-time ultrasound was a very accurate and precise method of predicting fat measurement in the carcass and combined with live weight and hip height was an accurate and precise method of estimating percentage of fat, kilograms of fat, kilograms of fat-free lean, and percentage of bone. An area that has not been thoroughly studied has been the use of ultrasound to relate how ribeye area and fat thickness measurements change over time. McLaren et al. (1989), working with swine, studied ribeye area and fat growth and examined prediction equations for estimated body composition and carcass characteristics based on serial real-time ultrasound measurements of loin eye area and backfat thickness. They concluded that carcass characteristics of market weight barrows and gilts can be predicted with reasonable accuracy by early serial weight and ultrasonic measures of backfat and loin eye area. They stated that this technique might prove valuable to seedstock swine producers wishing to make early selection decisions. Little research of this type has been published on beef cattle. Harada et al. (1989), working with Japanese Black bulls, concluded that ultrasound estimates of fat thickness, ribeye area, and marbling

score at 20 and 40 mo of age could be predicted by the use of ultrasound estimates at 14 mo of age. Turner et al. (1990) reported on the heritability of ultrasonic measurements in Hereford bulls. They found that ultrasound fat thickness and ribeye area were less heritable than carcass data traits and that ribeye area measurements should be adjusted for age, weight, and fat thickness effects.

The effects of frame size and breed on growth have been well documented; however, little work has been done on the effect of frame size on ribeye area changes over time. The concept of frame size, which is indicative of mature size, is part of the basis for the USDA feeder cattle grading system (USDA, 1979). Tatum et al. (1986) stated that cattle of large potential mature size (both among and within breeds) normally grow faster, attain a given degree of maturity at older ages, and begin to fatten at heavier weights than their smaller contemporaries. From their study of the effect of feeder cattle frame size on absolute growth rate and changes in carcass composition, Tatum et al. (1986) concluded that feeder cattle frame size classification was indicative of differences in absolute growth rate and slaughter weight at a specified level of fatness. Huffman et al. (1990) reported that steers of 1/2 and 3/4 Brahman breeding had faster weight gains and smaller ribeye areas than Angus steers. It is well documented that cattle of predominantly Brahman breeding produce carcasses with smaller ribeye areas than their contemporaries of predominantly Bos taurus breeding (Peacock et al., 1982; Luckett et al., 1975; Crockett et al., 1979; Young et al., 1978; and Lopes,

1986); however, information on how Brahman breeding affects ribeye area changes over time is lacking.

The literature is inconclusive concerning the effectiveness of ribeye area in predicting carcass cutability. However, assuming that it is a useful measurement, little work has been done to study how ultrasound technology can be utilized at an early age to evaluate ribeye area growth and to make early selection decisions. In general, this dissertation will address two major areas. The first study was designed to evaluate the relationship between ribeye area and carcass cutability in a subset of the current cattle population that represents a controlled range of carcass weight and ribeye area. The second study was designed to examine the changes that occur over time in ribeye area and fat thickness from a very young age to slaughter and how sex condition, breed type, and frame size may be related.

CHAPTER 2
THE RELATIONSHIP OF RIBEYE AREA TO MUSCLE-TO-BONE RATIO, LEAN PERCENTAGE AND RETAIL YIELD AT DIFFERENT FAT TRIM LEVELS

Introduction

The U.S. beef industry recently established a Value Based Marketing Task Force (Cattlemen's Beef Board, 1990) whose primary objective was to "improve efficiency of beef production by decreasing trimmable fat by 20% and increasing lean by 6% by 1995, while maintaining taste qualities." How will this be accomplished? During the late 1980s, retailers reduced fat trim on beef retail cuts from 1.3 to .4 cm (Cross et al., 1986), which resulted in a 27% reduction in fat in the retail case (Savell et al., 1990). These findings show promise for reaching the goal of reducing trimmable fat by 20% in the next 4 years, but how will the industry accomplish the goal of increasing lean by 6%?

Many beef cattle breed associations are collecting data needed to estimate expected progeny differences (EPDs) for ribeye area for beef cattle sire summaries, so producers will have an objective tool to use for selection of cattle with more muscle (Cundiff, 1991). Additionally, research is being conducted on instrumental methods to appraise value of live animals and carcasses, and the cross-sectional area of the longissimus at the 12^{th} - 13^{th} rib interface (ribeye area)

is considered one of the variables that should be assessed in this value determination (NCA, 1990). Questions have been raised concerning the effectiveness of ribeye area alone, or in combination with other carcass measurements, as a tool to predict carcass cutability. Cole et al. (1960) reported that ribeye area was associated with only 18% of the variation of percent separable carcass lean, and that carcass weight alone was more useful in predicting separable carcass lean than the multiple regression including both carcass weight and ribeye area. Ramsey et al. (1962) found that when ribeye area was omitted from yield grade calculations, the resulting yield grades were more highly related to separable lean and fat than when ribeye area was included. Epley et al. (1970) reported that ribeye area contributed little predictive value in estimating percent retail cuts of the four major primals. Other researchers, however, have found that ribeye area contributes significantly to multiple regression equations designed to predict carcass cutability (Pierce and Hallet, 1961; Brungardt and Bray, 1963; Hedrick et al., 1965; Abraham et al., 1968; Cross et al., 1973; Powell and Huffman, 1973; and Abraham et al., 1980). Despite the conflicting findings on the effect of ribeye area on cutability, ribeye area remains one of the independent variables in the USDA Yield Grade equation (USDA, 1965). Since 1965, USDA Yield Grades for beef carcasses have been the basis for estimating carcass cutability, and ribeye area is the only direct measurement of muscling used in the yield grade equation. This equation was developed from a representative sample of the U.S. cattle population in the 1960s, including

carcasses from all classes of sex condition and also from a wide range in carcass weight, fatness, and muscling. This broad sample allowed for accurate prediction of cutability (Hedrick, 1968), which was measured as percentage boneless retail cuts with 1.27 cm of subcutaneous fat.

Several measurements of cutability have been addressed in the literature. Berg and Butterfield (1966) suggest that when genetic comparisons of lean content are desired, muscle/bone ratio should be the end point evaluated. This is based on the fact that fat tissue is of low value and the level of fatness can readily be controlled environmentally. These authors point out that the market requirement at any particular time or locality would define the amount of fat desired. Many authors have assessed the amount of lean, as a percentage of carcass weight, which can be physically and/or chemically separated from fat and bone (separable lean). The end point for the yield grade equation is retail yield (lean and fat) of boneless subprimals trimmed to 1.27 cm of subcutaneous fat. Retail yield can be expressed at various levels of fatness. As packers and retailers reduce the amount of fat on boxed subprimals and retail cuts to .4 cm or less, measurements of muscle, such as ribeye area, may become more important in predicting cutability.

The current study was designed to evaluate the relationship between ribeye area and cutability in a subset of the present cattle population that represents a controlled range of sex class, carcass weight, and ribeye area. It is proposed that this subset accurately reflects typical beef carcasses (USDA, 1977), where

assessment of the relationship between ribeye area and carcass cutability is most crucial. The specific objectives of this study were: (1) to assess the relationship between ribeye area and various carcass cutability end points in a population of carcasses where, within specified carcass weight ranges, ribeye area varied; (2) to determine if differences in cutability exist between carcasses classified as having "above average," "average," or "below average" ribeye areas, relative to the USDA cutability equation; (3) to determine if fat trim level has an affect on the relationship between ribeye area and cutability; and (4) to develop the optimal prediction equation for carcass cutability from carcass and individual muscle measurements.

Materials and Methods

Carcass Selection

Figure 2-1 shows the distribution of carcasses (n=54) selected to represent six weight ranges (1 = 227 to 249, 2 = 250 to 272, 3 = 273 to 295, 4 = 296 to 318, 5 = 319 to 340, and 6 = 341 to 367 kg) and three ribeye area classifications (1 = below average, 2 = average, and 3 = above average). Carcasses originated from crossbred steers in three different feeding trials; however, steers were of similar age and pre-slaughter management treatments. Steers were produced at University of Florida beef research units and placed in the feedlot after weaning and were fed comparable rations until they reached pre-assigned slaughter end points based on ultrasonic fat thickness measured at the 12^{th} rib. Slaughter end

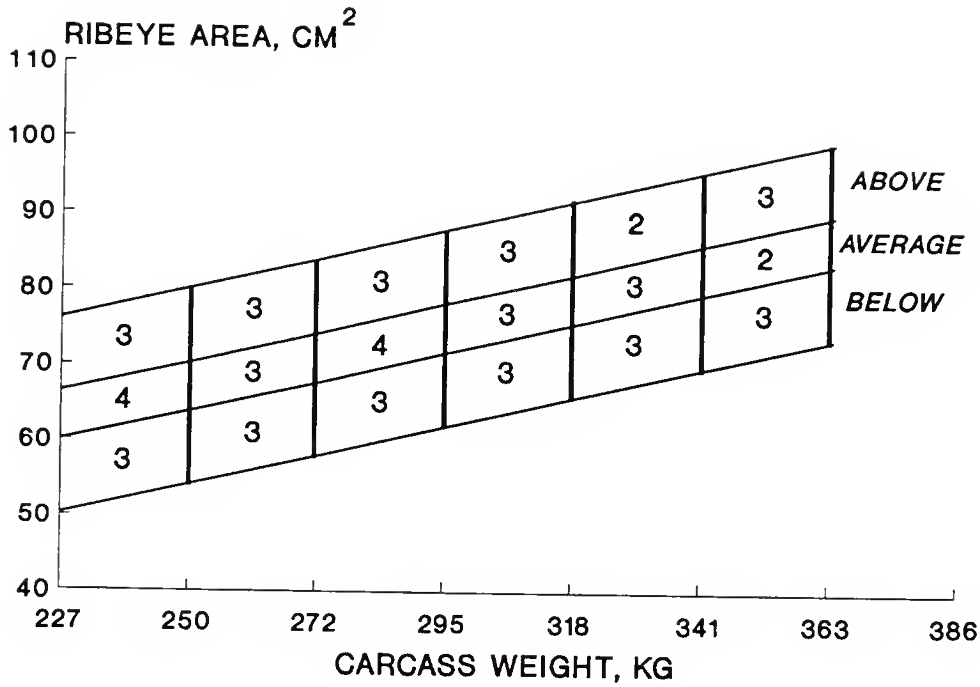

Figure 2-1. Number of carcasses selected for each ribeye area and carcass weight range.

point varied between trials from .9 to 1.3 cm of ultrasound subcutaneous fat. Fat thickness of the live animal was monitored monthly for the first 60 d of the feeding period and every 2 wk thereafter. Steers were removed from the feedlot when they reached their pre-assigned slaughter end point and were transported to either a commercial packing facility or the University of Florida Meat Laboratory for slaughter.

After routine slaughter procedures, carcasses were chilled for 24 h at 0° to 2° C, ribbed, and graded for USDA quality and yield grade factors by University of Florida personnel. Within each weight range approximately three carcasses were selected for each of the three ribeye area classifications. Average ribeye area was based on the USDA Yield Grade "short cut" adjustment for ribeye area. Ribeye area was assumed to be average if it was within 3.23 cm^2 of the calculated average for the particular hot carcass weight. Above and below average ribeye areas spanned a range from 3.23 cm^2 to 16.13 cm^2 above and below the calculated average within each weight range.

Carcass Fabrication

One side of each carcass, the side that had more bone after splitting, was weighed, trimmed of hanging tender, heart fat, channel fat, and other trim (thymus gland, tendinous edge of diaphragm and spinal cord). The side was then ribbed between the 12th and 13th ribs, quartered and weighed as outlined by USDA (1990). Sides were fabricated into wholesale cuts (Koch and Dikeman,

1977), trimmed to have not more than 2.54 cm of subcutaneous fat, and the components weighed. The wholesale cuts were further fabricated into boneless subprimals trimmed to .64 cm of subcutaneous fat. Weights of exposed intermuscular fat, trimmed subcutaneous fat, lean trim, and bone plus heavy connective tissue were recorded. Any intermuscular fat encountered during this phase of fabrication was kept separate and was combined with other intermuscular fat during the latter stages of fabrication. Wholesale cut fabrication procedures were in accordance with Institutional Meat Purchase Specifications (IMPS) for Fresh Beef (USDA, 1990). The IMPS boneless subprimals obtained from the forequarter were: IMPS #107--rib oven prepared (further fabricated into IMPS #112A--ribeye roll, lip on); IMPS #114--shoulder clod; IMPS #116A--chuck roll; IMPS #116B--chuck tender; IMPS #120--brisket, boneless, deckle off; IMPS #121E--skirt steak; and IMPS #117--foreshank. The IMPS boneless subprimals obtained from the hindquarter were: IMPS #176--strip loin; IMPS #182--sirloin butt; IMPS #189B--full tenderloin; IMPS #193--flank steak; IMPS #167--knuckle; IMPS #168--top round; and IMPS #170A--bottom round, heel out.

The following boneless IMPS subprimals were completely trimmed of all subcutaneous fat, and individual muscles were separated and completely trimmed of all intermuscular fat: IMPS numbers 112A; 114; 116A; 120; 176; 182; 189; 167; 168; and 170A. The "bridging" and "planing" techniques were followed as outlined in IMPS (USDA, 1990) to distinguish between intermuscular and subcutaneous

fat. Intermuscular fat, subcutaneous fat less than .64 cm, lean trim, and individual trimmed muscles were separated, weighed, and recorded. Lean trim removed during this phase of fabrication was kept separate from both hindquarter and forequarter lean trim.

Lean trim from the forequarter, lean trim from the hindquarter, lean trim from boneless subprimals and intermuscular fat were kept separate and were ground two times, mixed thoroughly, subsampled, vacuum packaged and frozen for subsequent lipid analysis. Lean trim subsamples were thawed overnight in an 8° to 10° C cooler, then ground finely and mixed prior to moisture and lipid analysis by the oven drying and soxhlet methods, respectively (AOAC, 1985).

Retail yields were calculated at three subcutaneous fat trim levels: 2.54 cm, .64 cm, and 0 cm. For each subcutaneous fat trim level, successively leaner chemical fat percentages were used to calculate lean trim yields. Retail yield at 2.54 cm included IMPS boneless subprimals with not more than 2.54 cm subcutaneous fat and lean trim adjusted to 25% chemical fat. Retail yield at .64 cm included IMPS boneless subprimals trimmed to .64 cm subcutaneous fat and lean trim adjusted to 20% chemical fat. Retail yield at 0 cm trim included IMPS boneless subprimals with all subcutaneous fat removed (with intermuscular fat intact), and lean trim adjusted to 10% chemical fat.

Muscle/bone ratio was calculated by two methods. First, muscle/bone ratio was calculated by adding defatted retail muscles to lean trim that had all "knife separable" fat removed and then dividing this value by total bone weight.

Secondly, fat-free muscle/bone ratio was calculated by adding defatted retail muscles to lean trim adjusted to 0% chemical fat and then dividing by total bone weight. It should be noted that defatted retail muscles contained intramuscular fat. Separable lean was calculated by adding defatted retail muscles to lean trim that had been adjusted to 5% chemical fat.

Additional measurements were made to assess the usefulness of various parts of the carcass in predicting cutability of the whole carcass. These included biceps femoris weight/femur weight ratio, longissimus weight, longissimus length, circumference of longissimus at the 12th rib, and circumference of longissimus at its widest point.

Statistical Analysis

Means, standard deviations, simple correlations, regression coefficients and standard partial regression coefficients were computed using SAS (1985). Single and multiple regression models were utilized to predict cutability end points using traditional carcass measurements. The General Linear Model procedure was utilized to determine if cutability differed among carcasses classified into three groups based on ribeye area. Stepwise regression was used to establish the best model for predicting cutability using carcass measurements, individual muscle measurements, and part-whole relationships of the carcass.

Results and Discussion

Table 2-1 shows mean values for carcass characteristics and cutability end points evaluated in this study. Coefficients of variation (CV) were much greater for carcass measurements (12.3% to 23.3%) than for carcass cutability end points (3.58% to 8.42%). The variability in ribeye area and hot carcass weight was established as a result of the selection of carcasses. The carcass selection criteria placed no restrictions on adjusted fat over the ribeye, and adjusted fat over the ribeye was variable, .38 cm to 1.52 cm, even though steers were assigned to be slaughtered when ultrasound fat thicknesses measured either .9, 1.0, or 1.35 cm. When compared with other experiments designed to assess cutability prediction, the range in adjusted fat thickness in this study was smaller (Ramsey et al., 1962; Abraham et al., 1980; May et al., 1990) or comparable (Crouse et al., 1975; Crouse and Dikeman, 1976). Variability relative to the mean (CV) increases as fat in the cutability end point decreases. This may be due to the fact that the means are getting smaller while variability is remaining constant, thus increasing CV. Additional cut fabrication, and consequent increased chance of cutting error, required to attain the lower fat end points, may also be a contributing factor.

Simple correlation coefficients (r) between carcass measurements and carcass cutability are presented in Table 2-2. Ribeye area was correlated with ($P < .01$) each of the carcass cutability end points ($r = .35$ to $.45$). Correlations for ribeye area with various measures of cutability are similar to previously published values: $r = .43$ for separable lean (Cole et al., 1960), $r = .45$ for retail yield at .94

TABLE 2-1. MEAN CARCASS AND CUTABILITY CHARACTERISTICS

Measurement	Mean	SD	Min.	Max.	CV,%[c]
Carcass measurements					
Ribeye area, cm^2	73.2	9.0	57.0	92.0	12.3
Hot carcass weight, kg	290.6	38.7	228.2	367.0	13.3
Adjusted fat over the eye, cm	1.03	.24	.38	1.52	23.3
Estimated KPH fat, %	2.1	.50	1.0	3.0	23.8
Marbling score[a]	336.7	68.6	170.0	520.0	20.4
USDA yield grade	2.7	.45	1.5	3.5	16.7
Carcass cutability endpoints					
Muscle/bone ratio	4.2	.33	3.5	5.2	7.9
Fat-free muscle/bone ratio	3.8	.32	3.2	4.7	8.4
Retail yield at 2.54 cm, %[b]	72.7	2.6	66.0	79.5	3.6
Retail yield at .64 cm, %[b]	66.8	2.7	60.4	73.2	4.0
Retail yield at 0 cm, %[b]	57.4	2.8	51.2	63.3	6.6
Separable lean, %[b]	55.7	2.7	49.9	61.8	4.9

[a] Marbling scores are as follows; 100-199 = practically devoid, 200-299 = traces, 300-399 = slight, 400-499 = small, 500-599 = modest.
[b] Calculated on a percentage of side weight basis.
[c] CV% = coefficient of variation.

TABLE 2-2. SIMPLE CORRELATION COEFFICIENTS BETWEEN MEASURES OF CARCASS CUTABILITY AND CARCASS TRAITS

Measurement	Muscle/bone ratio	Fat-free muscle/bone ratio	Retail yield, % 2.54 cm	Retail yield, % .64 cm	Retail yield, % 0 cm	Separable lean, %
Carcass measurements						
Ribeye area	.37**	.45**	.36**	.35**	.37**	.39**
Hot carcass weight	.19	.25*	.15	.12	.14	.16
Adj. fat over the eye	.27*	.19	-.26	-.41**	-.43**	-.48**
Estimated KPH fat, %	.10	.05	-.45**	-.39**	-.34*	-.31*
USDA yield grade	-.07	-.16	-.48**	-.56**	-.57**	-.59**
Marbling score	.12	.02	-.22	-.30*	-.26*	-.36**
Muscle measurements						
Longissimus circumference[a]	.24	.31*	.12	.14	.17	.09
Longissimus length, cm	.04	.10	.17	.18	.20	.20
Longissimus weight, kg	.24	.29*	.10	.15	.20	.21
Biceps femoris weight, kg	.32*	.41**	.47**	.46**	.47**	.49**
Femur weight, kg	-.22	-.13	.15	.21	.26	.28*
Biceps/femur ratio	.65**	.65**	.42**	.33*	.29*	.28*

* $p < .05$, ** $p < .01$.
[a] Circumference of the longissimus was measured at the 12th - 13th rib interface.

cm fat trim (Brungardt and Bray, 1963), r = .41 for retail product (Crouse and Dikeman, 1976), and r = .42 for percent boneless wholesale cuts trimmed to .64 cm (May et al., 1990). Hot carcass weight appeared to have no correlation with retail yield or separable lean and only a slight correlation ($r = .25$, $P < .05$) with fat-free muscle/bone ratio. Adjusted fat over the ribeye was positively correlated with muscle/bone ratio ($r = .27$, $P < .05$), but was not significantly correlated with fat-free muscle/bone ratio. This may be partly explained by the fact that the muscle value used in the muscle/bone ratio calculation contained fat that could not be removed with a knife, whereas the muscle value in the fat-free muscle/bone ratio calculation had all physical and chemical fat removed. Adjusted fat over the ribeye was negatively associated with retail yield at both .64 cm and 0 cm fat trim levels ($r = -.41$ and $r = -.43$, $P < .05$), showing that as carcass fat increases, retail yield at these fat trim end points decreases. Adjusted fat over the ribeye was negatively related ($r = -.48$, $P < .01$) to separable lean. These correlations are not as high as reported by other authors: r = -.76 for separable lean (Ramsey et al., 1962), r = -.82 for major boneless subprimals (Abraham et al., 1980), and r = -.52 for percent boneless wholesale cuts trimmed to .64 cm (May et al., 1990). The lower correlations found in this study might be explained by the narrower range in adjusted fat over the ribeye of the carcasses when compared to other studies. Steers in this study were slaughtered at similar fat thicknesses, therefore diminishing the variability in carcass fat thickness. Estimated kidney, pelvic, and heart fat showed a negative relationship (r = -.45

to −.34) with retail yield. These relationships show a decreasing trend as fat trim end point decreases. Separable lean was also significantly correlated ($r = -.31$) with estimated kidney, pelvic, and heart fat. As expected, USDA Yield Grade was negatively associated ($P < .01$) with retail yield at all three fat trim end points, and the relationships appeared to be stronger when cuts were trimmed to .64 cm or less. Separable lean had the greatest correlation with USDA Yield Grade ($r = -.59$, $P < .01$). USDA Yield Grade was not correlated with ($P > .05$) muscle/bone ratio. Marbling score was related to retail yield at .64 cm and 0 cm fat trim end points ($P < .05$) and to separable lean ($P < .01$). This is in agreement with May et al. (1990) who reported a correlation of $r = -.39$ between retail yield at .64 cm and marbling score. The simple correlation between marbling score and adjusted fat thickness was .47; therefore, carcasses with higher marbling scores tended to be fatter and therefore had lower yields at higher levels of marbling.

Correlations of individual muscle weights and measurements are presented in Table 2-2. Circumference of the longissimus at the 12^{th} - 13^{th} rib interface ($r = .31$, $P < .05$), and longissimus weight ($r = .29$, $P < .05$) were correlated with fat-free muscle/bone ratio. Longissimus length showed no correlation with carcass cutability. Weight of the biceps femoris, one of the heaviest muscles in the carcass, was significantly correlated with each of the six cutability end points. The femur, one of the heaviest bones in the carcass, was positively correlated with separable lean. When these two values were used to develop a ratio, significant

positive correlations were obtained for all cutability end points. Lunt et al. (1985) reported that the biceps femoris/femur ratio was useful in predicting cutability as measured by percentage separable lean.

Table 2-3 presents multiple linear regression information using independent variables of the USDA Yield Grade equation to predict each of six cutability end points. Each of the four yield grade variables were forced into the models. All models presented are significant ($P < .01$).

Ribeye area contributed ($P < .01$) to both muscle/bone ratio and fat-free muscle/bone ratio models. Standardized partial regression coefficients (b^1) show ribeye area to be the most important independent variable in these two models. The b^1 coefficients are smaller for separable lean ($P<.01$) and retail yield ($P<.05$) than for muscle/bone ratio, thus suggesting that ribeye area is more useful in predicting muscle/bone ratio end points. The b^1 coefficients do show, however, that ribeye area was still the most important independent variable in the models predicting separable lean and retail yield. Crouse et al. (1975) reported that when carcass weight was held constant, ribeye area was a very useful predictor of yield of retail cuts; however, when carcass weight was allowed to vary, ribeye area's usefulness diminished greatly. In this study, hot carcass weight was held relatively constant in relation to ribeye area.

Hot carcass weight was not a significant variable in any of the models examined. Griffin et al. (1989), using the same independent variables to predict yield of major boneless subprimals at different fat trim levels, found very similar

TABLE 2-3. MULTIPLE REGRESSION EQUATIONS AND STANDARD PARTIAL REGRESSION COEFFICIENTS FOR PREDICTING CARCASS CUTABILITY END POINTS FROM CARCASS MEASUREMENTS

End point	Intercept	b[a] and b[1]	Independent variable[b] REA	HCW	ADFOE	KPH	R^2	P[c]
Muscle/bone ratio	2.6	b	.02**	-.002	.52*	.01	.28	.0023
		b[1]	.62	-.24	.37	.02		
Fat-free muscle/bone ratio	2.2	b	.02**	-.002	.41*	-.01	.30	.0014
		b[1]	.66	-.21	.31	-.02		
Retail yield, 2.54 cm, %[d]	71.8	b	.14*	-.01	-.79	-2.3**	.35	.0002
		b[1]	.49	-.20	-.07	-.43		
Retail yield, .64 cm, %[d]	68.0	b	.14*	-.02	-3.0*	-1.8*	.37	.0001
		b[1]	.47	-.23	-.26	-.32		
Retail yield, 0 cm, %[d]	57.8	b	.15*	-.02	-3.35*	-1.46*	.36	.0002
		b[1]	.49	-.23	-.28	-.26		
Separable lean, %[d]	56.2	b	.14**	-.01	-4.1**	-1.2	.38	.0001
		b[1]	.46	-.20	-.35	-.22		

* = $P < .05$, ** = $P < .01$.
[a] b = parameter estimate, b[1] = standard partial regression coefficient.
[b] REA = ribeye area, HCW = hot carcass weight, ADFOE = adjusted fat over the ribeye, KPH = estimated kidney, pelvic, and heart fat.
[c] P = significance level for the overall regression model.
[d] Calculated as a percentage of side weight.

b values for hot carcass weight: yield at 2.54 cm fat trim, b = -.009; and yield at .64 cm fat trim, b = -.0109.

Adjusted fat over the ribeye has often been reported as the best single indicator of cutability (Powell and Huffman, 1973); however, in this study adjusted fat over the ribeye was not the most important variable in predicting cutability. In the muscle/bone ratio and fat-free muscle/bone ratio models, adjusted fat over the ribeye gave b^1 values that were half as large as the b^1 values for ribeye area. Adjusted fat over the ribeye was significant in the models predicting retail yield at .64 cm fat trim ($P < .05$, $b^1 = -.26$), retail yield at 0 cm fat trim ($P < .05$, $b^1 = -.28$), and percentage separable lean ($P < .01$, $b^1 = -.35$). As would be expected, adjusted fat over the ribeye became more important as fat percentage in the cutability end point decreased.

Kidney, pelvic, and heart fat was also included in the models presented in Table 2-3. It had no significant influence on the prediction of muscle/bone ratio, fat-free muscle/bone ratio or the percentage of separable lean. Kidney, pelvic, and heart fat was a factor ($P<.01$) in the prediction of retail yield at 2.54 cm fat trim and also was a significant factor in the prediction of retail yield at the trimmer cutability end points; however, as the amount of fat in the cutability end point decreased, the importance of kidney, pelvic, and heart fat diminished.

The R^2 values reported in Table 2-3 are substantially smaller than those reported by other authors. Crouse and Dikeman (1976), exploring the determination of retail product yield in beef, reported an R^2 of .69 for an

equation containing USDA Yield Grade variables of hot carcass weight, adjusted fat thickness, ribeye area and kidney, pelvic, and heart fat. Abraham et al. (1980) evaluated the usefulness USDA Yield Grades and reported R^2 = .80 for an equation containing yield grade variables. May et al. (1990) reported slightly lower values for predicting retail yield at .64 cm subcutaneous fat trim (R^2 = .59). Murphey et al. (1960) analyzed data of the original study from which the USDA Yield Grade was derived and reported simple correlation coefficients between the actual and predicted retail yield were highly significant (r = .91). Hedrick (1968) stated that when the USDA Yield Grade equation was applied to a more homogenous group of carcasses than was used in the 1960 study, the relationships are likely to be lower than originally reported. Griffin et al. (1989) presented multiple regression equations containing the yield grade variables that had lower R^2 values, (R^2 = .38 for predicting retail yield with 2.54 cm subcutaneous fat trim to R^2 = .49 for predicting retail yield with .64 cm of subcutaneous fat trim) more similar to those reported in Table 2-3.

Figures 2-2 through 2-7 provide a graphical representation of the linear regression of cutability on ribeye area. All simple regression models were significant ($P < .05$) for predicting each of the cutability end points. Each of the regression lines are rather similar with R^2 values ranging from R^2 = .12 for retail yield at .64 cm fat trim to R^2 = .20 for fat-free muscle/bone ratio. These data are in agreement with Cole et al. (1960), who reported that when ribeye area was used alone to predict separable lean from the carcass, only 18% of the variation

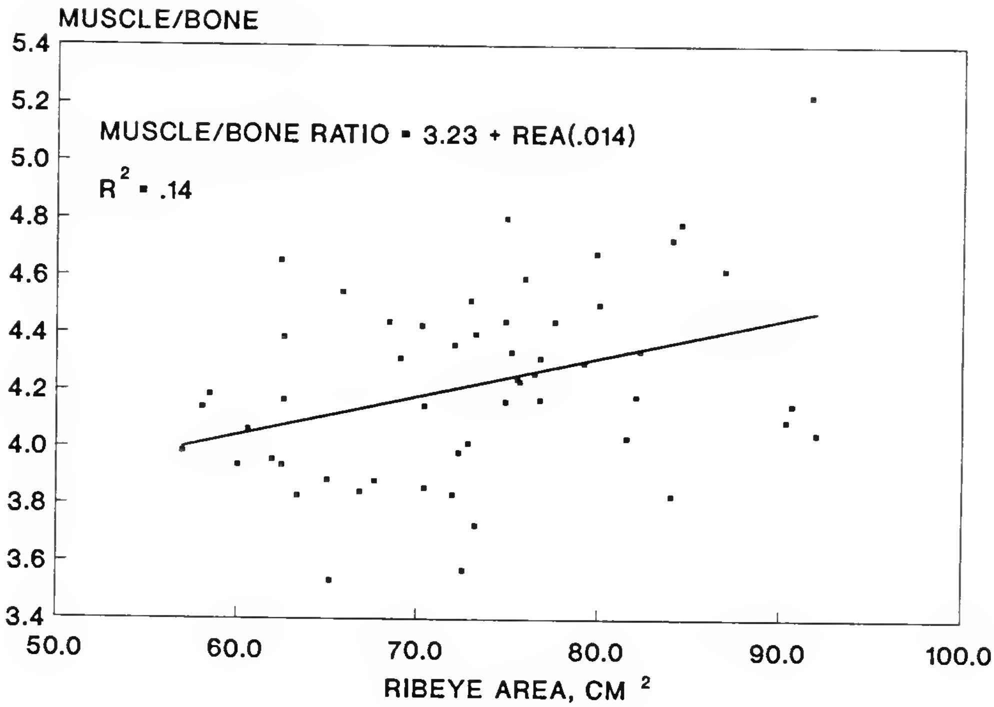

Figure 2-2. Linear regression of muscle/bone ratio on ribeye area.

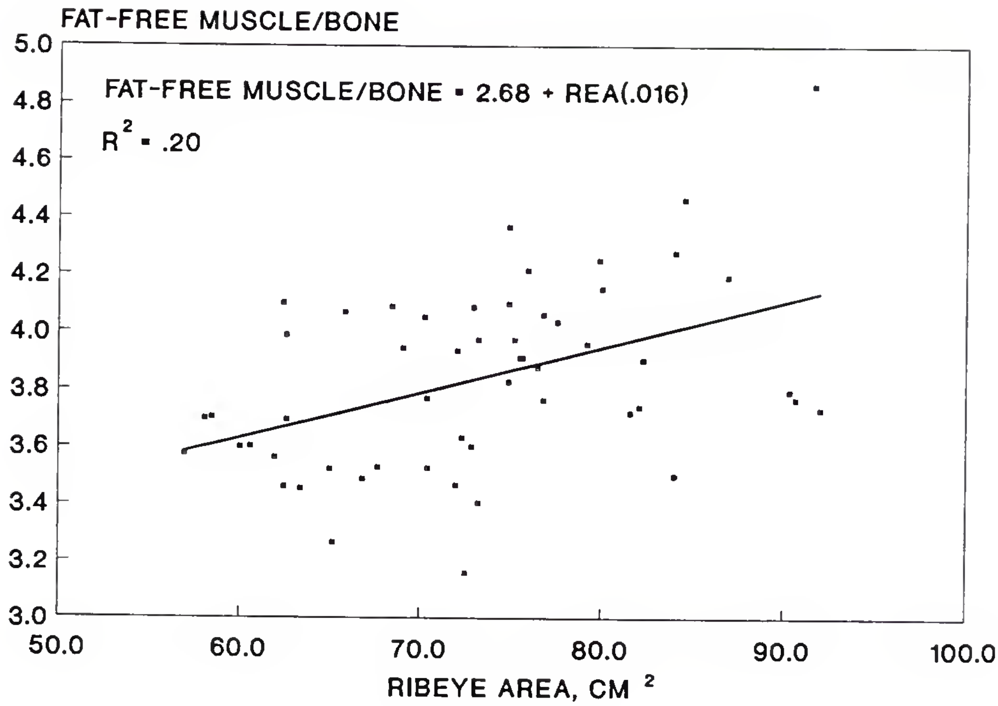

Figure 2-3. Linear regression of fat-free muscle/bone ratio on ribeye area.

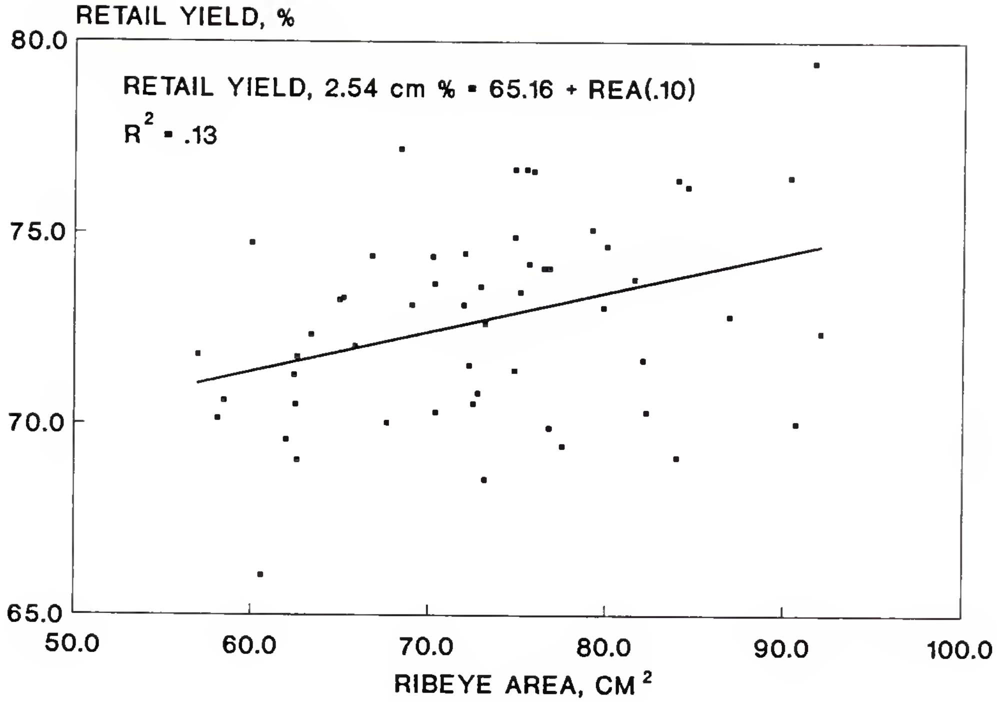

Figure 2-4. Linear regression of retail yield at 2.54 cm of subcutaneous fat trim on ribeye area.

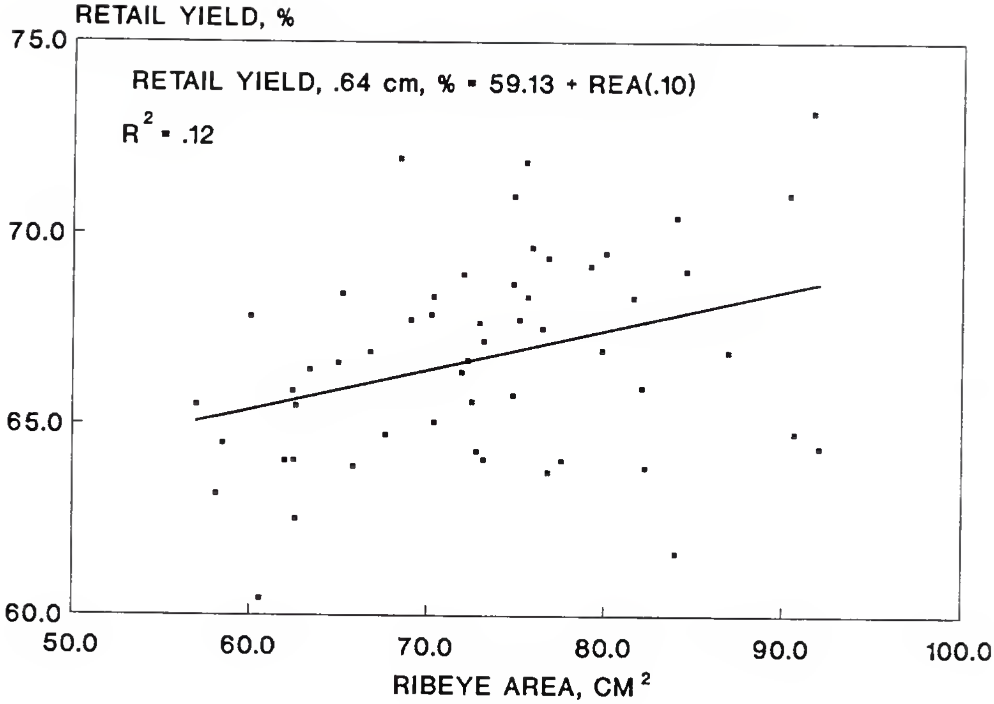

Figure 2-5. Linear regression of retail yield at .64 cm of subcutaneous fat trim on ribeye area.

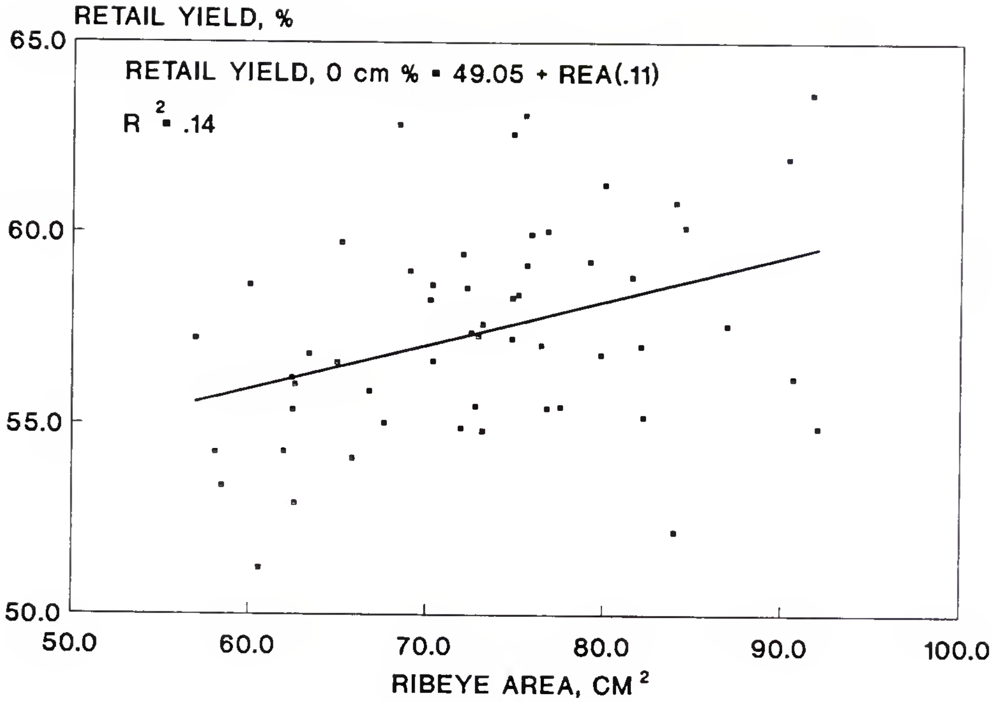

Figure 2-6. Linear regression of retail yield at 0 cm of subcutaneous fat trim on ribeye area.

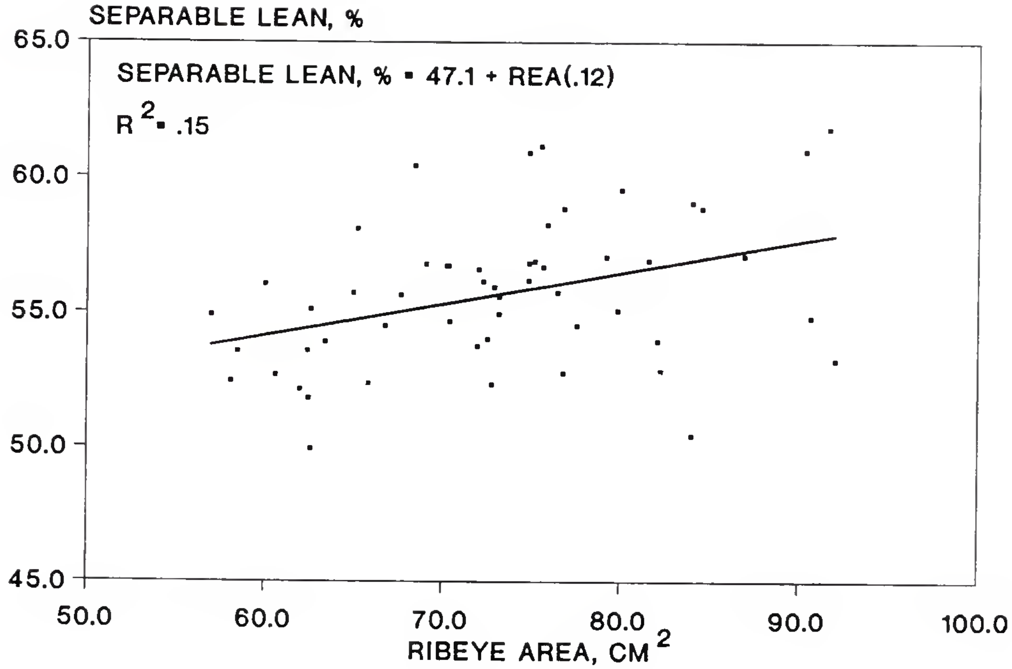

Figure 2-7. Linear regression of separable lean percentage on ribeye area.

could be explained. Much of the current literature in this area fails to provide information regarding the usefulness of ribeye area as a single regressor for predicting cutability. The single linear regressions were included in this manuscript to gain a better understanding of the usefulness of ribeye area in explaining the variation that exists in cutability.

Table 2-4 gives least squares means for carcass cutability end points for each of the specified ribeye area classifications. These classifications were based on the USDA Yield Grade "short cut" method for determining ribeye area adjustment, which utilizes the relationship between ribeye area and hot carcass weight. A carcass which would have a preliminary yield grade adjustment for ribeye area of plus or minus .2 would be considered average, an above average carcass would represent an adjustment of −.2 to −.45, and a below average carcass would represent an adjustment of +.2 to +.45 to the preliminary yield grade. This was examined to determine if a carcass that is generally considered as "above average" for muscling (ribeye area) is actually different in cutability from a carcass that is generally considered "below average" for muscling. Although there appears to be a tendancy for the above average group to have higher cutability, no significant differences were found between classification groups. A greater range in ribeye area in the carcass population might provide the opportunity to detect differences between these classification groups; however, in a population selected to represent the majority of "typical" carcasses, using the ribeye area/weight relationship to segregate carcasses into cutability groups appears to be ineffective.

TABLE 2-4. LEAST SQUARES MEANS FOR CARCASS CUTABILITY END POINTS BY RIBEYE AREA CLASSIFICATION WITH ADJUSTED FAT OVER THE RIBEYE AS A COVARIATE

End point	Ribeye area classification			SE	P-value[b]
	below	average	above		
Muscle/bone ratio	4.1	4.1	4.3	.07	.12
Fat-free muscle/bone ratio	3.8	3.8	4.0	.07	.09
Retail yield, 2.54 cm, %[a]	72.4	72.5	73.2	.62	.41
Retail yield, .64 cm, %[a]	66.5	66.6	67.1	.60	.29
Retail yield, 0 cm, %[a]	57.1	57.3	57.9	.61	.21
Separable lean, %[a]	55.4	55.3	56.2	.58	.18

[a] Calculated as a percentage of side weight.
[b] P-value for the overall least squares model.

Table 2-5 presents models to predict cutability generated from stepwise regression. All carcass measurements, including individual muscle and bone measurements, were considered as candidate variables. The level for entry into the model was $P < .15$ and 12 variables were considered. Ribeye area was the only carcass measurement that entered into all six of the models. A model containing ribeye area, biceps femoris weight, and biceps femoris/femur ratio had an R^2 value of .56 for predicting muscle/bone ratio. A slightly different model was obtained for predicting fat-free muscle/bone ratio ($R^2 = .58$), the only difference being the substitution of femur weight for biceps femoris weight. Models for estimating retail yield end points were all different however, each used ribeye area, estimated kidney, pelvic, and heart fat, and biceps weight.

The results of this study indicate significant, but low relationships exist between carcass characteristics and carcass cutability. These results are in general agreement with much of the current literature. Possible explanations for the lack of predictability of carcass cutability may stem from the fact that the variation in carcass cutability is relatively low within a population of typical slaughter cattle.

Implications

This study presents a unique look at the usefulness of ribeye area in equations designed to predict beef carcass cutability. Although current literature on this subject is not in full agreement, the results presented from this study indicate that within a population of carcasses that represent the majority of

TABLE 2-5. STEPWISE REGRESSION EQUATIONS FOR PREDICTING CUTABILITY END POINTS FROM CARCASS MEASUREMENTS.

		EQUATION VARIABLES[a]									
	Intercept	REA	HCW	ADFOE	KPH	LMCIR	BICEPS	FEMUR	B\F	C(p)[b]	R^2
Muscle/bone ratio	1.65	.02					-.08		.86	3.6	.56
Fat-free muscle/bone ratio	1.80	.02						-.11	.52	2.9	.58
Retail yield, 2.54 cm, %[c]	70.4	.09	-.05		-1.91		1.19			6.2	.53
Retail yield, .64 cm, %[c]	70.6	.07	-.03	-5.11	-1.14		1.37			5.9	.60
Retail yield, 0 cm, %[c]	57.1	.09	-.05	-3.32	-.98		1.34			4.4	.57
Separable lean, %[c]	69.1	.07		-8.2		-.89	1.38	-2.38		2.9	.65

[a] REA = ribeye area, HCW = hot carcass weight, ADFOE = adjusted fat over the eye, KPH = estimated kidney, pelvic and heart fat, LMCIR = longissimus muscle circumference at the widest point, BICEPS = biceps femoris weight, B/F = biceps femoris/femur ratio. Other candidate variables tested but not meeting the P < .15 level for entry into the model, were marbling score, longissimus circumference at the 12th rib, longissimus length and longissimus weight.

[b] C(p) criterion is used to avoid overspecification of the regression model.

[c] Calculated on a percentage of side weight basis.

"typical" slaughter cattle, where variation in carcass weight and ribeye area were controlled, ribeye area was as valid as any other carcass measurement in predicting beef carcass cutability. However, only 12% to 20% of the variation in cutability could be explained by ribeye area alone, and there were no statistical differences in cutability between carcasses classified as "above average," "average," or "below average" for ribeye area. Biceps femoris weight, femur weight and the ratio of these two variables proved valuable as predictors of cutability. Therefore, programs aimed at determining beef carcass value should incorporate ribeye area along with other carcass variables into prediction equations. If feasible, major muscle and/or bone weights could greatly enhance the predictive value of regression equations designed to predict cutability.

CHAPTER 3
RIBEYE AREA AND FAT THICKNESS GROWTH DURING THE EARLY LIFE OF BEEF CALVES

Introduction

Animal scientists and cattlemen are faced with the task of identifying individual breeding cattle that will perform to a specified level for a given trait. Numerous traits have been evaluated over the years; however, carcass traits have received a considerable amount of attention during the past decade due to consumer demands for leaner meat products. Historically, carcass trait information has been difficult to obtain on breeding cattle because of the tremendous expense involved in collecting carcass data on progeny of individual animals. However, during the last decade, the advent of real-time ultrasound has provided the opportunity for the measurement of ribeye area and fat thickness on the live animal at a relatively low cost and with reliable accuracy.

The area of cattle growth and development has been of interest to those involved in animal production for decades, and complete understanding of the complexities of the bovine growth curve has yet to be attained. Butterfield (1964) stated that all organisms, except the most simple, undergo changes of form due to differential growth rates of their constituent parts, and the early works of Hammond (1921), Palsson (1932), and Huxley (1932) all described developmental

changes that occur in young, growing ruminant animals. The classical work of Butterfield (1964), through the use of individual muscle dissection, established "standard muscle groups", where muscles were grouped according to their relative postnatal growth. The muscles surrounding the spinal column were classified as average-developing muscles because their weight in relation to that of total carcass muscle remained virtually unchanged during post-natal life. Berg and Butterfield (1966) reported that major changes in the musculature of cattle occur in the first 6 to 8 months of life. According to the body growth gradient theory, Huxley (1932) stated that the cross-sectional area of the longissimus muscle at the last rib was the best method to estimate the degree of muscle development. Since those early days, numerous other researchers have proven the usefulness of longissimus muscle area measurement in estimating muscle development (Hedrick et al., 1965; Powell and Huffman, 1973; and Abraham et al., 1980). Therefore, a measurement made at weaning (about 7 to 9 mo of age) of the longissimus dorsi (ribeye area) has the potential to be a reliable predictor of total carcass muscle. Growth of the longissimus after weaning should be relative to the growth of other muscle groups of the carcass, since the longissimus muscle was in the group classified as average developing by Butterfield (1964).

Understanding when to obtain and how to utilize ultrasound information has become an area of great importance; however, little work has been published on this subject. Harada et al. (1989), working with Japanese Black bulls, concluded that ultrasound fat thickness and ultrasound ribeye area at 20 mo and

at 30 mo of age could be accurately predicted from ultrasound estimates of fat thickness and ribeye area at 14 to 16 mo of age. Turner et al. (1990) suggested that ultrasound measurements should be taken as close to 365 d of age as possible. From an economical standpoint, however, cattlemen would prefer obtaining ultrasound measurements early in the growth cycle so that selection decisions could be made before bulls reach a year of age and incur added expenses associated with feeding and management. Ultrasound measurements of ribeye area have the potential to be more accurate on lighter weight cattle, before the image of the ribeye becomes large and difficult to capture with the ultrasound equipment. Additionally, if cattle are in good condition (> 10 mm), fat thickness measurements may be less accurate. Turner et al. (1990) reported that ultrasound technicians participating in the BIF certification consistently underestimated actual carcass fat thickness as the animals got fatter. To address the problem of when ultrasound measurements should be taken, information on how ultrasonically determined muscle and fat measurements change over time and how these changes are related to weight changes would be useful.

Berg and Butterfield (1966) found that the amount of fat on cattle is under a high degree of environmental (management) control. Body composition can vary greatly in the percentage of fat, depending on stage of growth and plane of nutrition. Fat thickness is best utilized for describing changes in fatness within populations of cattle that are of similar age and have been under similar management.

Frame size and/or breed type may have an effect on the growth rate of ribeye area and fat thickness. Frame size has been shown to have an influence on cattle growth (BIF, 1990). In general, research shows that small frame cattle tend to grow at a slower rate, whereas large frame cattle tend to exhibit faster growth (Tatum et al., 1986). Huffman et al. (1990) found breed type had a significant effect on weight gain and ribeye area size.

Very little data exist showing the changes that occur over time in ribeye area and fat thickness from a very young age to slaughter, and how breed type and/or frame size may be related. Development of growth curves for ribeye area and fat thickness, both measured by ultrasound, would prove valuable in understanding how to utilize ultrasound data on young breeding cattle. Therefore, the objectives of this study were: 1) to develop and describe growth curves for weight, ultrasound ribeye area, ultrasound ribeye area / 45.4 kg live weight, and ultrasound fat thickness in cattle; and 2) to determine what effects sex condition, frame size, and breed type have on these growth curves.

Materials and Methods

Experimental Procedure

One hundred and ninety five steer (n = 99) and heifer (n = 96) calves were used in the preweaning phase of this study. These calves were from cows of five breed groups [Angus (A), Brahman (B), 3/4A:1/4B, 1/2A:1/2B, and Brangus (5/8A: 3/8B) and sires of six breed groups (the five breed groups of dams and

1/4A:3/4B)]. Fifteen separate calf breed percentages were represented ranging from 100% Angus to 100% Brahman; however, for simplification of analysis and interpretation, calves were classified into five "breed groups" as follows; BG 1 = 81% to 100% Angus, BG 2 = 61% to 80% Angus, BG 3 = 41% to 60% Angus, BG 4 = 21% to 40% Angus, and BG 5 = 0% to 20% Angus. The number of calves in each breed group and their distribution are displayed in Table 3-1. Calves were born on the University of Florida's Pine Acres Research Unit, Citra, from December, 1988 to May, 1989.

Beginning in February, when the oldest calves were about 2 months of age, two Beef Improvement Federation (BIF) certified ultrasound technicians obtained ultrasound images approximately every 4 to 6 wk until weaning. Calves born early in the season (December to February) were weaned in September, and calves born late (March to May) were weaned in October. This allowed for four to seven pre-weaning measurements per calf, depending on the age of the calf.

After weaning, calves were allotted to three different experiments, not associated with this study, where nutritional treatment was the area of interest. For this reason some postweaning measurements were not obtained and some animals were not utilized in the postweaning data set. Heifers were only utilized in the preweaning period. Fifty-six of the steer calves were utilized in the postweaning measurements. After weaning, steer calves were maintained on bahiagrass pasture for approximately 75 d, then placed in the feedlot. Steer calves were fed a finishing ration for no less than 98 d. Postweaning weight and

TABLE 3-1. DISTIRBUTION OF CALVES BY FRAME GROUP AND BREED GROUP.

	Breed group				
Frame group	BG1	BG2	BG3	BG4	BG5
Steers					
FG1	7	2	2	0	0
FG2	9	4	6	2	1
FG3	3	7	10	9	6
FG4	1	4	5	5	8
FG5	0	0	2	6	0
Heifers					
FG1	21	5	6	3	0
FG2	7	5	16	7	1
FG3	0	3	3	9	9
FG4	0	1	0	0	1

ultrasound measurements were taken every four weeks until all steers were slaughtered. Steers were removed from the feedlot and slaughtered when they reached either .9 or 1.3 cm of ultrasound fat thickness determined at the 12^{th} - 13^{th} rib interface. This allowed for four to eight postweaning weight and ultrasound measurements, depending on when slaughter occurred.

Hip height was determined at weaning and was used with age to calculate frame size as described by the Beef Improvement Federation (BIF, 1990). In this study, frame size ranged from .96 to 7.03. To study the influence of frame size on growth, calves were grouped into frame size groups which attempted to cover the range represented, while keeping numbers of calves within classification groups as even as possible. Five frame size groups were created for steers (FG1 = <3, FG2 = 3 to 4, FG3 = 4 to 5, FG4 = 5 to 6, FG5 = >6) and four for heifers (FG1 = <3, FG2 = 3 to 4, FG3 = 4 to 5, FG4 = >5). Table 3-1 shows the distribution of calves by frame group and breed group.

An Aloka 210-DX B-mode scanner equipped with a UST-5021 probe was used to obtain cross-sectional images of the longissimus dorsi at the 12^{th} - 13^{th} rib interface. This probe operates at 3.5 Mhz with an image refreshing rate (frame rate) of 10 or 20 frames/s. Dynamic, or "real-time" ultrasound images were recorded on a VHS video cassette recorder and stored for subsequent analysis. All preweaning ultrasound scans were taken using the single-screen mode. Because of the size of the ribeye at weaning, a desirable image in the single-screen mode could not be obtained; therefore, the split-screen mode had to be

utilized. The split-screen mode required the use of a calibrated probe guide that allows the operator to freeze the left screen that contains half of the desired picture, and then "match" the right screen to complete the desired picture. As suggested by Simm (1983), all recorded scans were interpreted by one individual, a BIF certified technician. Animorph, a video image analysis system, was used to measure fat thickness and ribeye area from the ultrasound recordings. This system allows the user to "grab" a single frame from the video tape, thus allowing an interface with the computer. A trackball was then used to measure fat thickness at a point, laterally from the spine, three-fourths of the distance across the longissimus muscle. The trackball was used to trace the area of the longissimus muscle (ribeye area). Duplicate scans of each animal were measured, and when the first two values differed by more than 10%, a third measurement was taken. A mean was computed on the two closest measurements.

Statistical Analysis

All analyses were done separately for preweaning and postweaning measurements because calves were treated similarly prior to weaning and all one-hundred and ninety five calves were utilized, however; after weaning calves were allotted to three different experiments where nutritional treatment was the area of interest. For this reason some postweaning measurements were not obtained. All heifers were utilized preweaning. Postweaning measurements were utilized from fifty-six (n=56) steer calves that were backgrounded for 75 d and then placed in

the feedlot. Because of the repeated measurements on each animal, random coefficient regression analysis, as described by Gumpertz and Pantula (1989) and Littell (1990), was used. Linear and quadratic models were fitted to the data with age as the independent variable and weight, ultrasound ribeye area, ultrasound ribeye area/45.4kg live weight (REACWT), and ultrasound fat thickness as dependent variables. Estimates of the intercept and coefficients for the linear and quadratic terms were obtained for each calf. A new data set was then constructed which contained estimates of these regression parameters for each calf. Using estimates of the regression parameters as dependent variables, analysis of variance procedures were employed to test for differences between steer and heifer calves. Sex condition was found to have a significant effect on all regression coefficients except for the quadratic weight term and the linear and quadratic fat thickness terms. Because of the sex effect, further analyses was conducted separately for steers and heifers. Analysis of variance procedures were then utilized to determine the effects of frame size and breed type on the dependent variables. Least squares means were computed and mean separations were performed and considered significant at $P < .05$.

Results and Discussion

Table 3-2 presents means and standard deviations for age, weight, ribeye area, REACWT, and fat thickness at each measurement time. Table 3-2 shows that preweaning weight and ribeye area increased over time for both sexes. Steers

TABLE 3-2. MEANS (STANDARD DEVIATION) FOR SERIAL MEASUREMENTS BY SEX.

Measurement period	Steers					Heifers				
	Age, d	Weight, kg	REA, cm^2[a]	REACWT, cm^2[b]	FAT, cm[c]	Age, d	Weight, kg	REA, cm^2[a]	REACWT, cm^2[b]	FAT, cm[c]
February	33 (17)	68.3 (16)	16.3 (5)	10.8 (3)	.33 (.07)	33 (16)	65.0 (16)	15.8 (5)	11.4 (2)	.32 (.04)
March	43 (27)	80.2 (25)	19.3 (6)	11.2 (2)	.34 (.07)	46 (25)	75.3 (25)	19.3 (5)	11.4 (2)	.34 (.08)
April	74 (32)	101.7 (32)	22.8 (6)	10.3 (2)	.33 (.06)	79 (32)	97.5 (32)	21.8 (6)	10.3 (2)	.34 (.06)
May	110 (38)	134.0 (42)	25.8 (8)	9.2 (1)	.32 (.06)	117 (36)	129.8 (39)	25.7 (7)	9.2 (2)	.34 (.11)
July	161 (38)	184.5 (44)	33.6 (8)	8.6 (1)	.37 (.10)	168 (36)	175.8 (40)	32.5 (7)	8.7 (2)	.39 (.10)
September	209 (38)	233.5 (45)	40.7 (8)	8.1 (1)	.42 (.08)	216 (36)	221.3 (42)	39.2 (9)	8.1 (2)	.46 (.10)
Weaning[d]	227 (27)	247.5 (40)	41.6 (8)	7.9 (1)	.42 (.07)	226 (30)	225.9 (39)	38.6 (8)	7.9 (1)	.46 (.10)
October	252 (38)	245.7 (41)	39.7 (7)	7.3 (1)	.42 (.08)	259 (36)	231.7 (36)	37.8 (7)	8.3 (1)	.44 (.10)
November	293 (38)	---	---	---	---	---	---	---	---	---
December	303 (38)	259.2 (39)	51.7 (9)	9.1 (1)	.45 (.11)	---	---	---	---	---
January	332 (38)	320.1 (47)	56.8 (9)	8.2 (1)	.59 (.16)	---	---	---	---	---
February	366 (38)	396.4 (59)	64.3 (10)	7.2 (1)	.78 (.16)	---	---	---	---	---
March	390 (38)	438.2 (60)	73.7 (10)	7.7 (1)	.91 (.25)	---	---	---	---	---
April	428 (38)	493.7 (44)	78.0 (14)	7.2 (1)	.92 (.18)	---	---	---	---	---
May	474 (38)	487.2 (76)	81.9 (10)	7.6 (1)	.92 (.16)	---	---	---	---	---

[a] REA = ultrasound ribeye area, cm^2.
[b] REACWT = (ultrasound ribeye area, cm^2 * 45.4 kg) / weight, kg.
[c] FAT = ultrasound fat thickness, cm.
[d] Weaning occurred in September for older calves (n=142) and October for younger calves (n=56).

were heavier and had slightly larger ribeye areas at each measurement period than heifers. Ribeye area expressed relative to body weight, REACWT, showed a decreasing trend through the preweaning period and heifers had REACWT values that were as large as or larger than steers at every measurement period. Preweaning fat thickness showed little change and was very similar between sexes. Postweaning, steer weight increased up to about 490 kg and then leveled off. Ribeye area of the steers was increasing even at the last measurement period, and REACWT declined until leveling off around 7.2 to 7.7 cm^2/45.4 kg, after about 60 d on feed. Fat thickness increased up to about .9 cm and then appeared to level off. These phenomena were due to steers being removed from the feedlot and slaughtered when half reached .9 and the other half reached 1.3 cm of outside fat.

Littell (1990) pointed out the difficulties associated with analysis of repeated measurement data using conventional multivariate and univariate techniques. Traditionally, repeated measurement data have been analyzed as "split-plot in time" experiments with individual animals being treated as main-plot units and the measurements on the animals at particular points in time treated as the sub-plot units. These techniques present unique problems associated with the correlation structure and the validity of using such techniques on unbalanced data is questionable. Additionally, these methods overlook the regression on time, or as it applies to this study, age. Gumpertz and Pantula (1989) and Littell (1990) proposed utilizing the Random Coefficient Regression Model to analyze repeated measures data. This method entails developing regression curves for treatment

groups by fitting a regression curve to each experimental unit, and then averaging the coefficients of the curves over the units. Treatment groups can then be compared by applying typical analysis of variance procedures to the group means of the coefficients. This method has been employed in this study to describe and compare differences that exist in the growth curves of cattle of different sex condition, frame size, and breed group.

Sex Condition

Table 3-3 presents regression coefficients for weight between steers and heifers. Weight gain was linear ($P<.0001$) during the preweaning phase and steers gained faster ($P<.0001$) than heifers (.9816 kg/d vs. .8968 kg/d). Figure 3-1 displays this relationship graphically and provides the regression equations used to plot these lines. Steers and heifers had similar weights at approximately 30 d of age; however, steers exhibited faster ($P<.0001$) growth to weaning. The postweaning weight gain coefficient for steers is presented in Table 3-3 and the predicted growth curve is presented graphically in Figure 3-2. The linear relationship between age and weight is higher for steers postweaning versus preweaning (1.5215 kg/d vs. .9816 kg/d). A quadratic curve best explains weight gain in steers postweaning (Figure 3-2). Steers gained weight at a very rapid rate, during the feedlot phase, from about 300 d of age to 450 d of age. This was expected since steers were receiving a high energy diet ad libitum and were slaughtered at constant fat end points of .9 cm or 1.3 cm of subcutaneous fatness.

TABLE 3-3. REGRESSION COEFFICIENTS BY SEX CONDITION FOR WEIGHT CHANGES WITH AGE.

Regression[a]	Sex condition						P-value
	Steers			Heifers			
Preweaning, n		99			97		
linear	.9816	±	.014	.8968	±	.014	.0001
quadratic	.00068	±	.0002	.00085	±	.0002	.4317
Postweaning, n		56					
linear	1.5215	±	.023		N/A		
quadratic	.0050	±	.0005		N/A		

[a] Indicates the linear and quadratic regressions of weight on age.

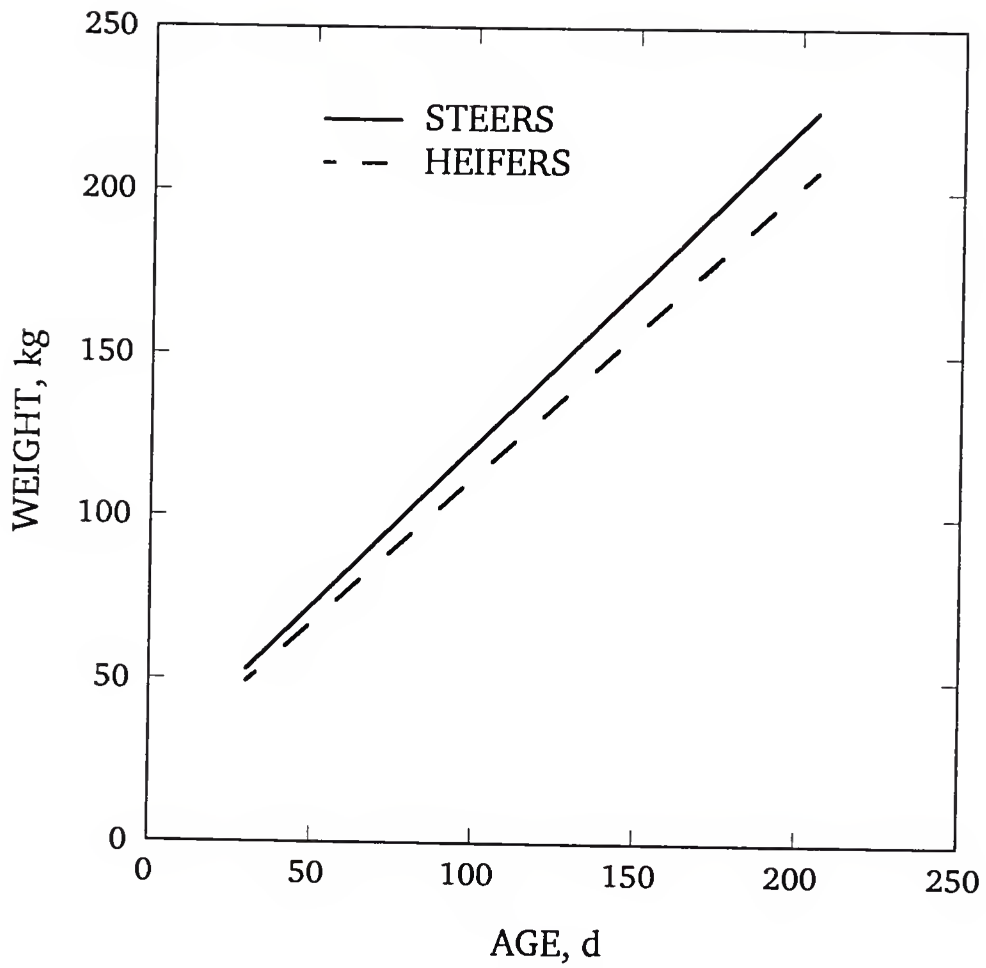

Figure 3-1. Preweaning weight gain by sex condition. Equations are as follows: steers, weight=23.34 + age(.982), and heifers, weight=22.30 + age(.897).

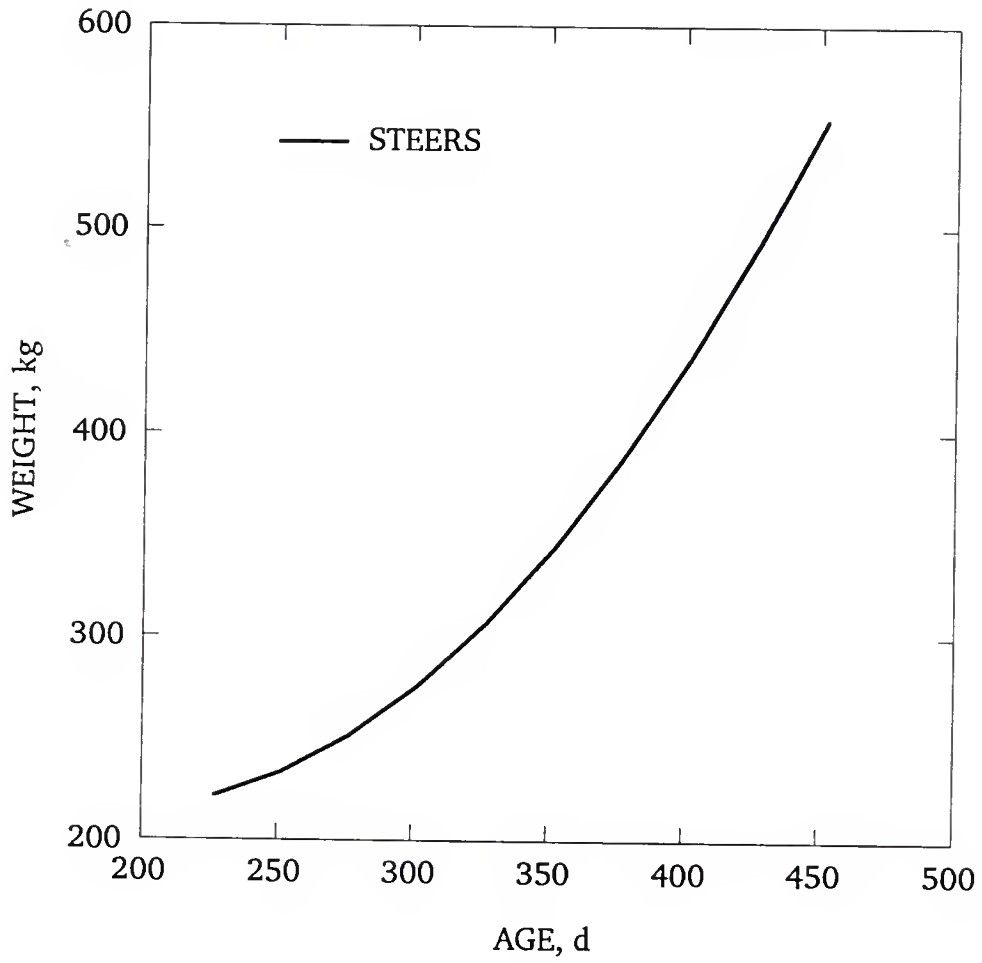

Figure 3-2. Postweaning weight gain of steers. Equation as follows: $weight = 396.68 - age(1.90) + age^2(.005)$.

Most cattle reach these endpoints while still in the phase of rapid growth. Huffman et al. (1990) reported on steers of Brahman and Angus breeding and found average daily gains of 1.69 kg/d for steers fed to .83 cm of subcutaneous fat to 1.62 kg/d for steers fed to 1.31 cm of subcutaneous fat.

Table 3-4 presents regression coefficients for ribeye area of steers and heifers. As with weight, steers exhibit faster linear ribeye area growth than heifers in the preweaning phase ($P<.0155$). Quadratic curves appear to fit the preweaning data and are presented graphically in Figure 3-3. Figure 3-3 shows that steers and heifers had very similar ribeye area measurements at about 30 d of age. Steers appeared to grow faster than heifers from about 30 to 150 d of age, and then growth slowed slightly so that steers and heifers had similar ribeye areas at weaning. Table 3-4 shows linear ribeye area growth in steers is much more rapid postweaning vs. preweaning. Figure 3-4 shows that steer ribeye area growth followed weight gain during the postweaning period. Steers were experiencing rapid weight gain because they were on a high energy diet fed ad libitum, and were slaughtered when they attained either .9 or 1.3 cm of outside fat, before muscle development plateaued.

To account for the positive correlation between weight and ribeye area, a variable was created, REACWT, to assess ribeye area on a relative body weight basis. Table 3-5 presents regression coefficients by sex condition for REACWT change with age. During the preweaning phase, the linear response was not different ($P>.05$) between steers and heifers; however the quadratic regression

TABLE 3-4. REGRESSION COEFFICIENTS BY SEX CONDITION FOR RIBEYE AREA CHANGES WITH AGE.

Regression[a]	Sex condition						P-value
	Steers			Heifers			
Preweaning, n		99			97		
linear	.1390	±	.004	.1251	±	.004	.0155
quadratic	-.0003	±	.00006	.00005	±	.00006	.0013
Postweaning, n		56					
linear	.2399	±	.006		N/A		
quadratic	.0005	±	.0002		N/A		

[a] Indicates the linear and quadratic regressions of ultrasound ribeye area on age.

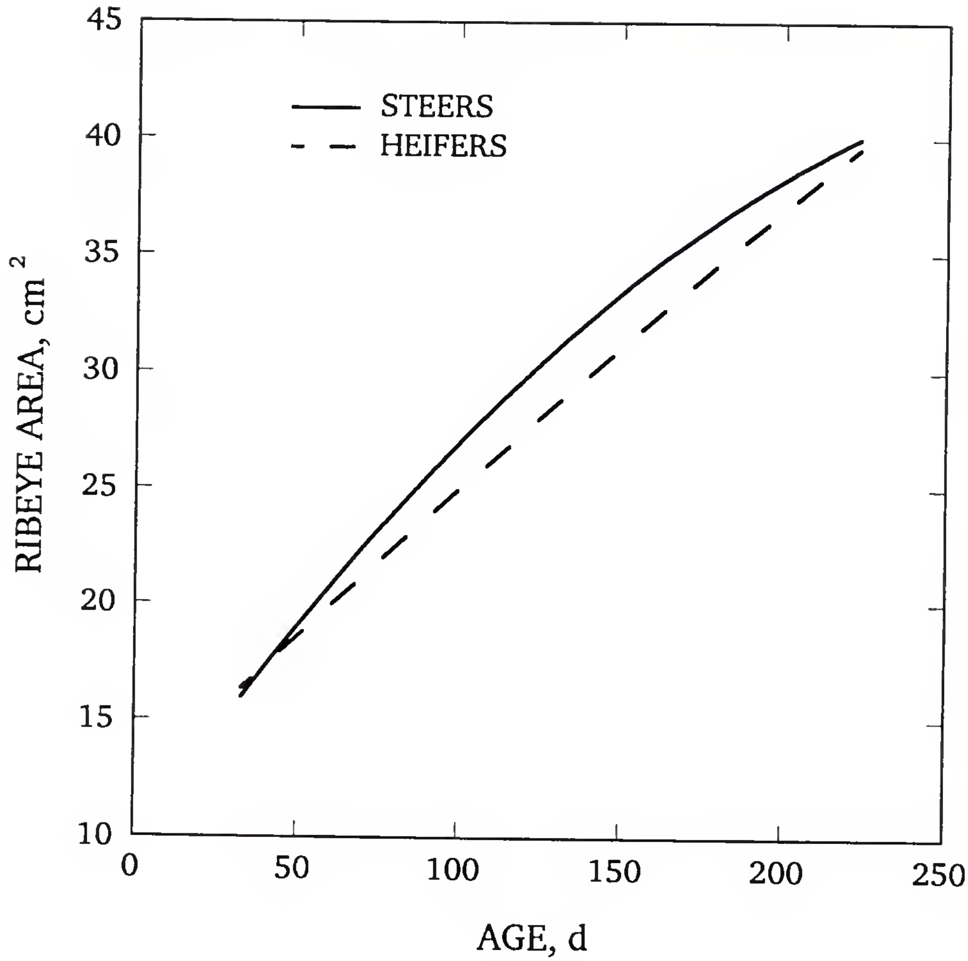

Figure 3-3. Preweaning ribeye area growth by sex condition. Equations are as follows: steers, ribeye area=9.54 + age(.204) - age^2(.0003), and heifers, ribeye area=11.94 + age(.135) - age^2(.00005).

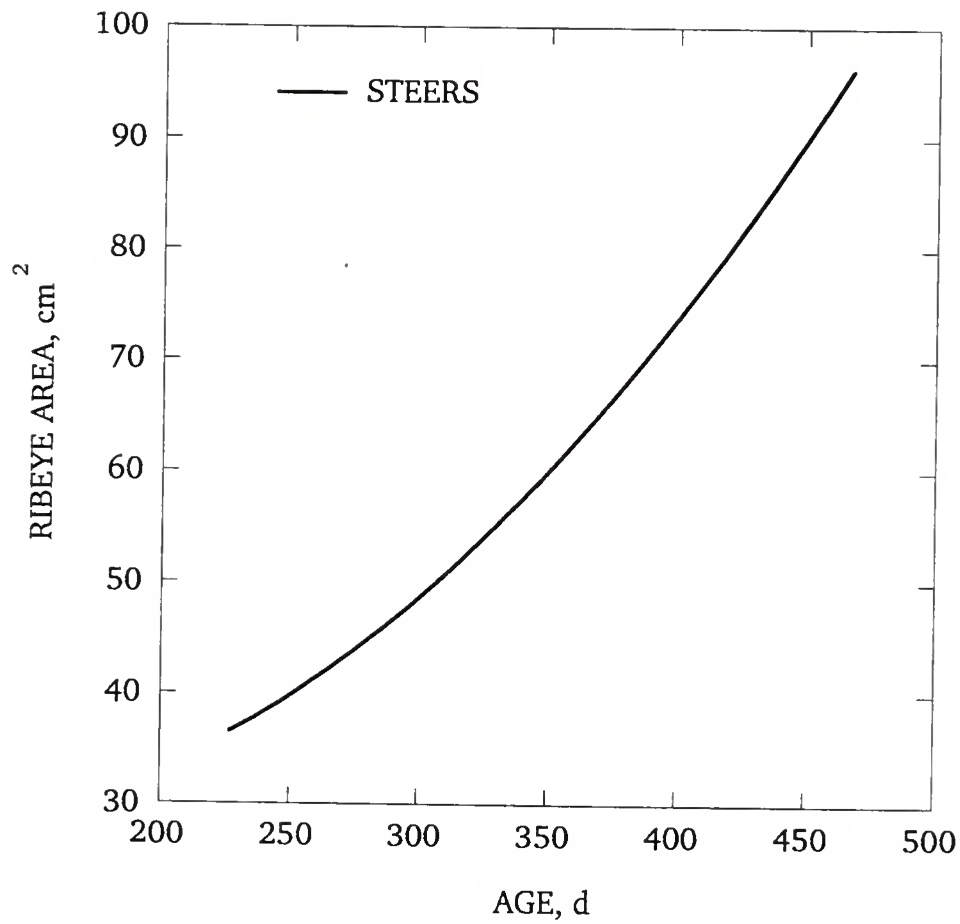

Figure 3-4. Postweaning ribeye area growth of steers. Equation is as follows: ribeye area=32.667- age(.096) + age^2(.0005).

TABLE 3-5. REGRESSION COEFFICIENTS BY SEX CONDITION FOR RIBEYE AREA/45.4 KG LIVE WEIGHT CHANGES WITH AGE.

Regression[a]	Sex condition						P-value
	Steers			Heifers			
Preweaning, n		99			97		
linear	-.0187	±	.0011	-.0210	±	.0011	.1286
quadratic	.000006	±	.00002	.000095	±	.00002	.0097
Postweaning, n		56					
linear	-.0033	±	.0011		N/A		
quadratic	-.00009	±	.00002		N/A		

[a] Indicates the linear and quadratic regressions of ultrasound ribeye area/45.5 kg live weight on age.

was different ($P<.05$) and is expressed graphically in Figure 3-5. This illustrates clearly that REACWT favors lighter weight cattle, which was a concern expressed by Turner et al. (1990). Heifers showed a greater rate of decline in REACWT than steers. Apparently, the growth impetus for ribeye area as a function of weight is higher in steers than in heifers. Heifers were growing rapidly and ribeye area was increasing; however, a greater percent of the weight must have been directed toward growth of other tissues, such as fat or organs associated with the reproductive tract. Postweaning the linear response was not different ($P>.05$) between sexes. Figure 3-6 displays the quadratic response of REACWT on age in steers. During the postweaning phase, REACWT only ranged from approximately 7 to 8 cm^2/45.4kg with the peak corresponding to the period shortly after steers were placed on feed.

Table 3-6 presents regression coefficients for outside fat thickness between steers and heifers. Preweaning, there were no differences between the sexes for fat thickness; however, there was a tendency ($P=.0979$) for heifers to deposit fat more rapidly than steers (.0007 cm/d vs .0006 cm/d). Although the difference in these growth coefficients is small, it may explain, in part, why REACWT declines at a faster rate in heifers than in steers. As expected, postweaning fat deposition was rapid for steers (Figure 3-7). Steers increased rapidly in fat deposition soon after being placed in the feedlot, at about 300 d of age.

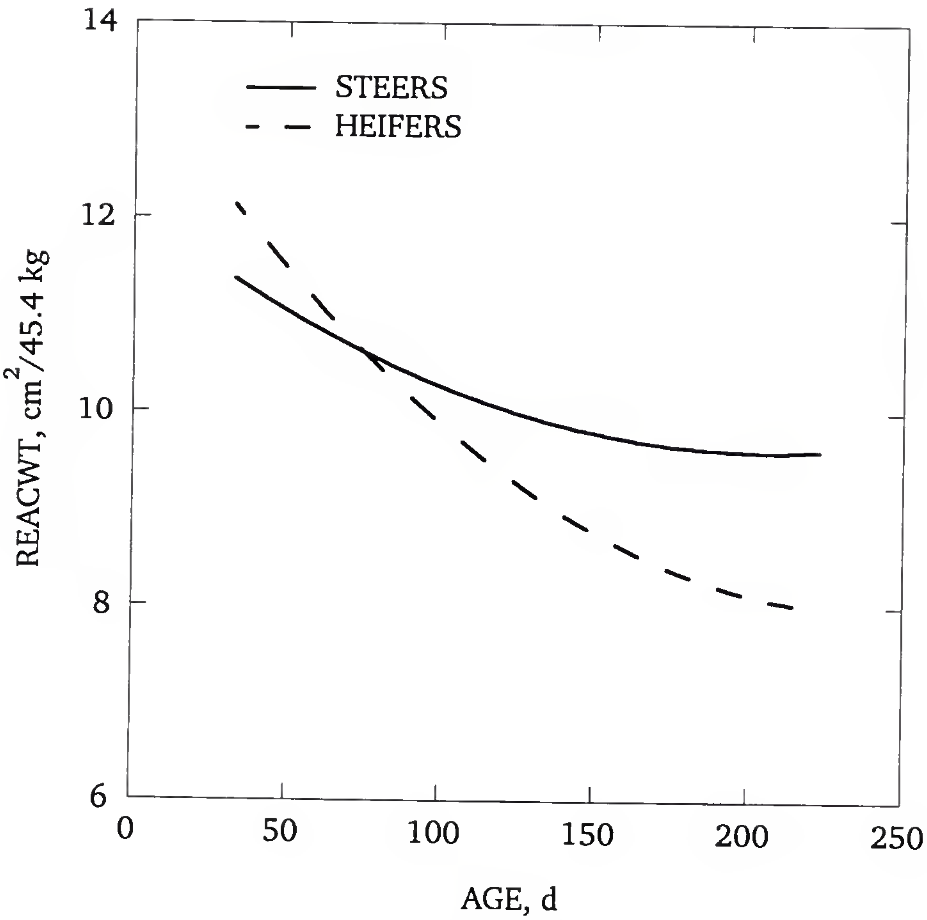

Figure 3-5. Preweaning change of ribeye area / 45.4 kg live weight by sex condition. Equations are as follows: steers, REACWT=12.10 - age(.024) + age^2(.000006), and heifers, REACWT=13.54 - age(.046) + age^2(.0001).

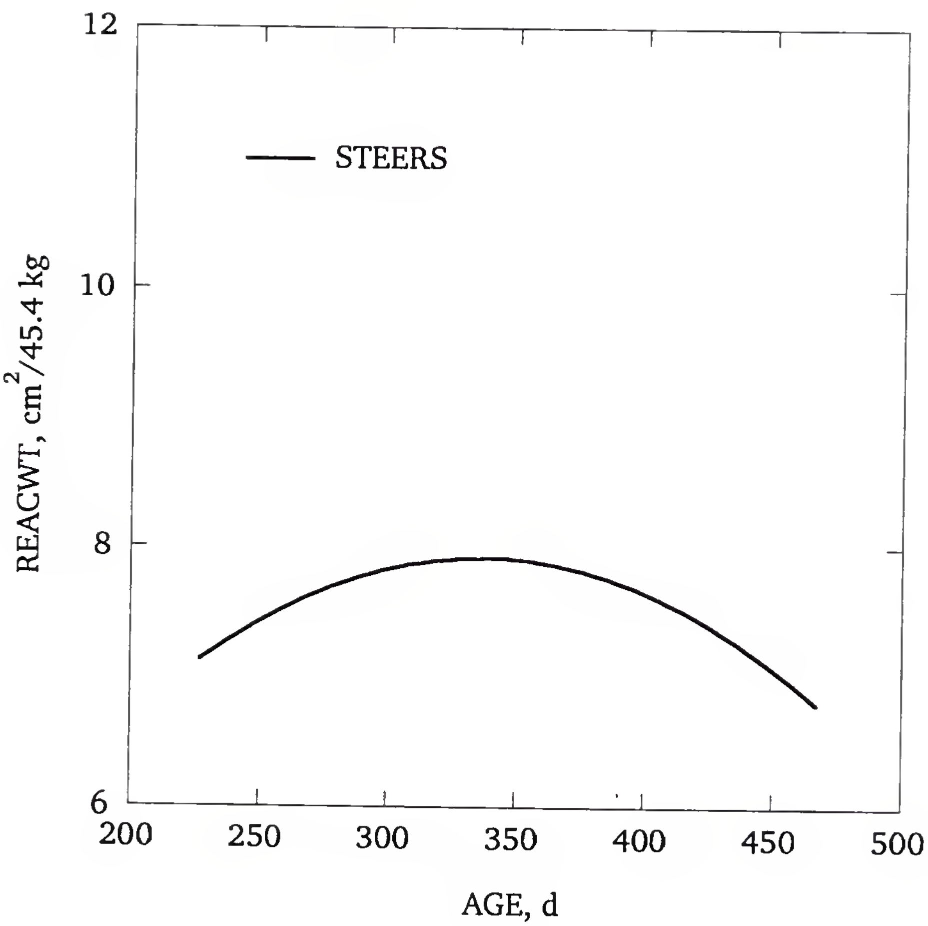

Figure 3-6. Postweaning change of ribeye area / 45.4 kg live weight of steers. Equations is as follows: REACWT = .48 + age(.044) - age^2(00007).

TABLE 3-6. REGRESSION COEFFICIENTS BY SEX CONDITION FOR FAT THICKNESS CHANGES WITH AGE.

Regression[a]	Sex condition						P-value
	Steers			Heifers			
Preweaning, n		99			97		
linear	.0006	±	.00004	.0007	±	.00005	.0990
quadratic	.000002	±	.0000009	.000002	±	.000001	.5952
Postweaning, n		56					
linear	.0038	±	.0001		N/A		
quadratic	.00002	±	.000003		N/A		

[a] Indicates the linear and quadratic regressions of ultrasound fat thickness on age.

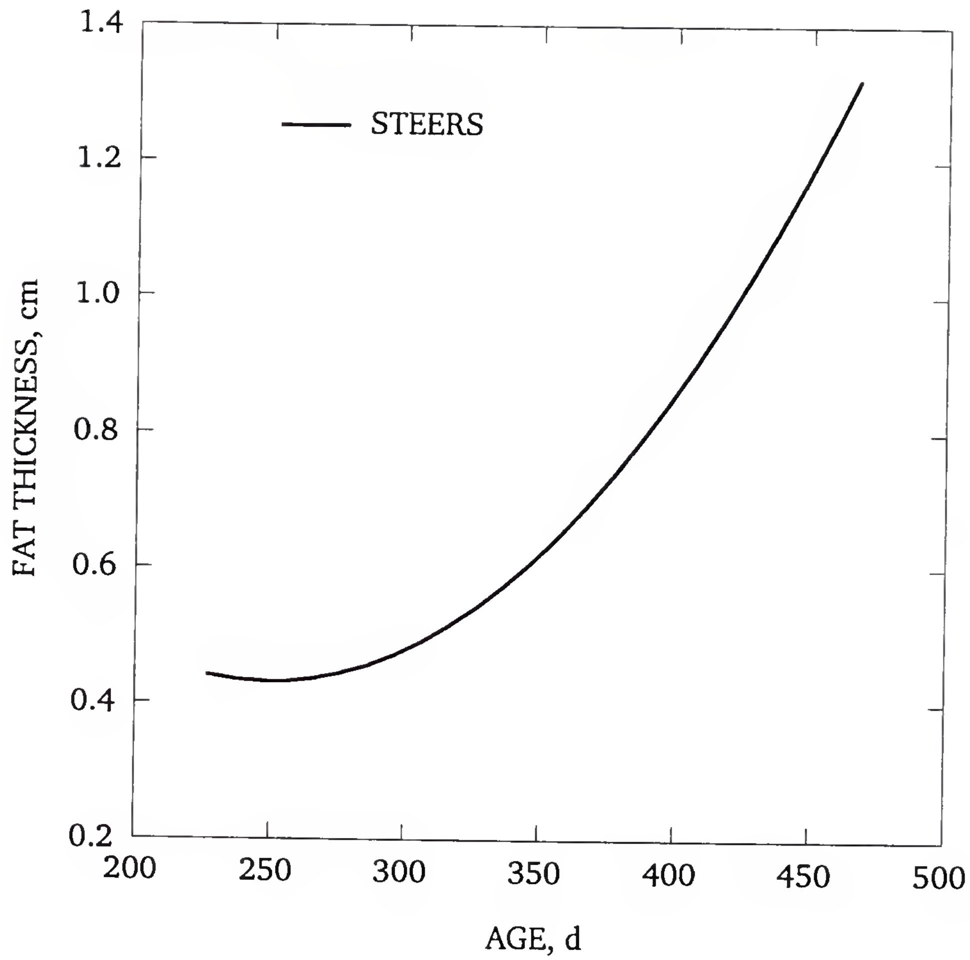

Figure 3-7. Postweaning fat thickness growth of steers Equation is as follows: fat thickness=1.60 - age(.009) + age^2(.00002).

Frame Size

The linear effect of age on weight gain was different among frame groups for both steers and heifers (Table 3-7, Figures 3-8 and 3-9). Smaller frame steers (FG1 and FG2) grew slower ($P<.05$) than steers in the larger framed classes (FG3 and FG4) and all of these groups increased in weight at a slower rate ($P<.05$) than steers in FG5. This may be partly explained by the fact that the large frame steers may weigh less in relation to their mature weight, and therefore they experience faster growth. These results are in general agreement with Thonney et al. (1981), who demonstrated that large frame Holstein steers grew faster than small frame Angus steers. Apparently, the genes that affect growth also affect frame size. Fitzhugh and Taylor (1971) have shown that mature size exerts an influence on cattle growth and carcass composition via genetic relationships to growth rate, maturing rate and weight at the onset of fattening. Heifers showed the same trend in the preweaning phase with FG1 heifers having the slowest ($P<.05$) rate of linear growth. Heifers in FG2 had slower growth ($P<.05$) than heifers in FG4, and heifers in FG3 were intermediate and not significantly different from heifers in FG2 and FG4. Quadratic equations for weight gain of heifers by frame size classification are shown in Figure 3-9. The largest frame heifers (FG4) start out heavier and grow at a slightly faster rate than the other, smaller frame groups. It should be pointed out, however, that coefficients from heifers in FG4 were calculated from measurements on two animals and therefore inferences concerning this group should be made with

TABLE 3-7. REGRESSION COEFFICIENTS BY FRAME SIZE CLASSIFICATION FOR WEIGHT CHANGES WITH AGE IN STEERS AND HEIFERS.

Regression[a]	Frame size classification[b]					RMSE[c]
	FG1	FG2	FG3	FG4	FG5	
Preweaning						
Steers, n	11	22	35	23	8	
linear	.9064[d]	.9118[d]	.9859[e]	1.0192[e]	1.1508[f]	.127
quadratic	.0015	.0009	.0006	.0002	.0010	.002
Heifers, n	35	36	24	2	N/A	
linear	.8343[d]	.9052[e]	.9607[ef]	1.0738[f]	N/A	.117
quadratic	.0013[d]	.0010[d]	.00003[e]	.0007[de]	N/A	.0004
Postweaning						
Steers, n	3	15	20	13	5	
linear	1.5802	1.4889	1.4647	1.6433	1.4945	.235
quadratic	.2200	.2530	.2400	.2377	.2184	.056

[a] Indicates the linear and quadratic regressions of live weight on age.

[b] Frame size calculated by the Beef Improvment Federation method where smaller numbers equate to smaller frame scores, (FG1 = frame <3, FG2 = frame 3-4, FG3 = frame 4-5, FG4 = frame 5-6, FG5 = frame >6).

[c] Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each frame size classification.

[def] Means within the same row with different superscripts differ (P< .05).

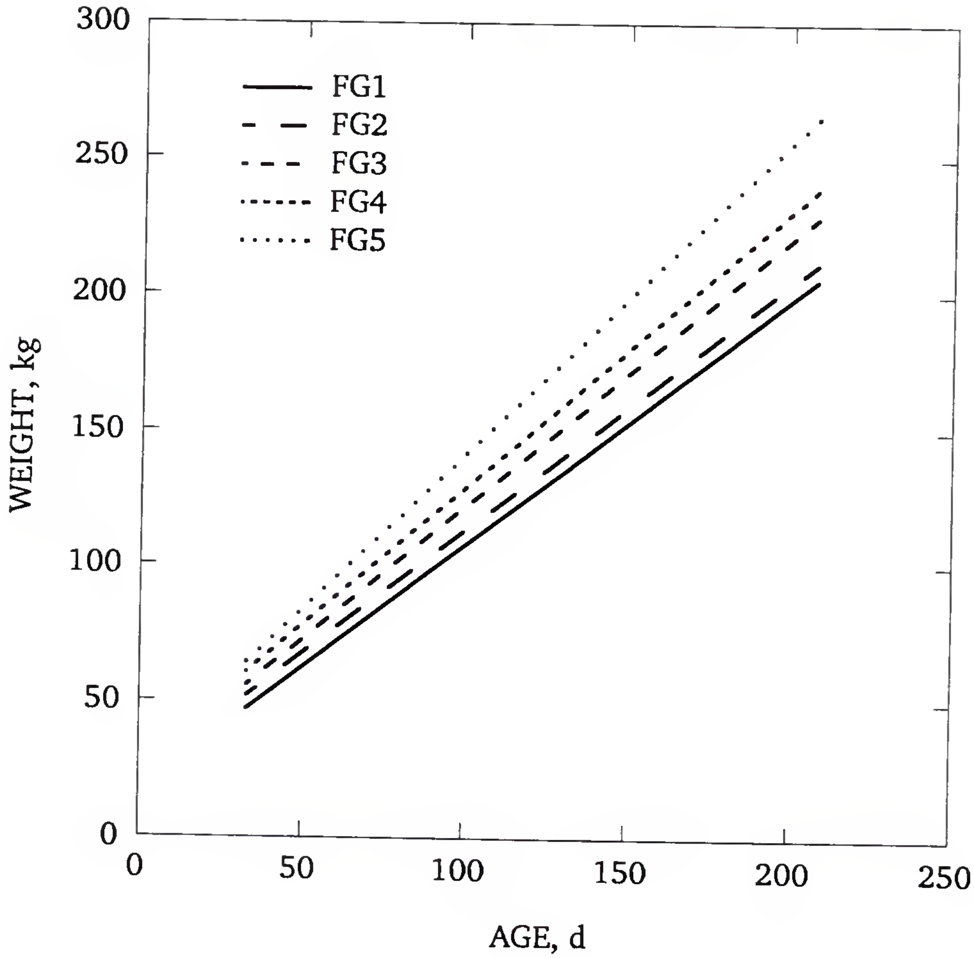

Figure 3-8. Preweaning weight gain of steers among frame size classifications. Equations are as follows: FG1, weight=17.06 + age(.906); FG2, weight=21.89 + age(.912); FG3, weight= 3.24 + age(.986); FG4, weight=26.94 + age(1.010); FG5, weight=26.06 + age(1.151).

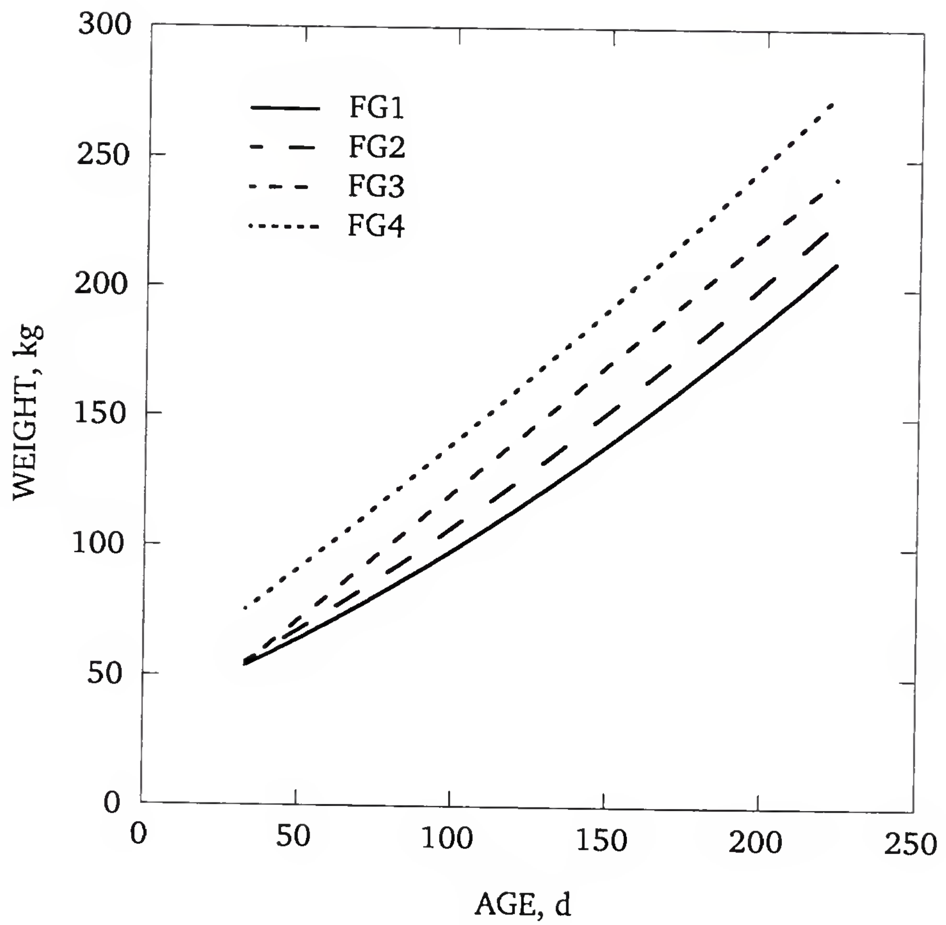

Figure 3-9. Preweaning weight gain of heifers by frame size classification. Equations are as follows: FG1, weight=36.18 + age(.502) + age^2(.001); FG2, weight=33.06 + age(.644) + age^2(.001); FG3, weight= 22.27 + age(.984) + age^2(.00003); FG4, weight=46.69 + age(.861) + age^2(.0007.

caution. This will hold true for heifers from FG4 throughout this manuscript. Unexpectedly, postweaning weight regression coefficients for steers were not different among frame size classifications. The lack of sufficient animal numbers in FG1 (n=3) and FG5 (n=8), postweaning, may be a contributing factor to the reason no differences were detected. Tatum et al. (1986), who used USDA feeder cattle grades to estimate frame size, reported that large frame steers grew at a faster rate, during a 140 d finishing period, than small frame steers, while medium frame steers were intermediate.

Significant differences were found for daily increases in ribeye area among frame size groups of steers (Table 3-8 and Figure 3-10). Steers from FG1 and FG2 had similar growth rates (P>.05) for ribeye area; however, ribeye area growth was significantly slower for steers from FG1 and FG2 than for steers from the other three frame size groups (FG3, FG4, and FG5). The later three groups did not differ from each other (P>.05). Heifer calves showed a similar trend in ribeye area growth (Table 3-8 and Figure 3-11). The two smaller frame groups were not different (P>.05); however, they had significantly slower ribeye area growth than heifers from FG3. Postweaning, steer ribeye area growth did not differ among frame size classifications.

Table 3-9 shows that only slight differences in REACWT were found among frame size groups. Figure 3-12 shows the linear regression of REACWT on age in preweaning measurements of heifers. Heifers from FG3 showed a slightly slower rate of decline in REACWT with increasing age, than FG1 and

TABLE 3-8. REGRESSION COEFFICIENTS BY FRAME SIZE CLASSIFICATION FOR RIBEYE AREA CHANGES WITH AGE IN STEERS AND HEIFERS.

	Frame size classification[b]					
Regression[a]	FG1	FG2	FG3	FG4	FG5	RMSE[c]
Preweaning						
Steers, n	11	22	35	23	8	
linear	.1194[d]	.1230[d]	.1446[e]	.1476[e]	.1606[e]	.038
quadratic	-.0001	-.0001	-.0003	-.0005	-.0004	.0007
Heifers, n	35	36	24	2	N/A	
linear	.1143[d]	.1180[d]	.1517[e]	.1228[de]	N/A	.038
quadratic	.000008	.00002	-.00021	-.00037	N/A	.0004
Postweaning						
Steers, n	3	15	20	13	5	
linear	.2200	.2530	.2400	.2377	.2184	.056
quadratic	.0013	.0009	.0004	.0002	-.0003	.001

[a] Indicates the linear and quadratic regressions of ultrasound ribeye area on age.

[b] Frame size calculated by the Beef Improvment Federation method where smaller numbers equate to smaller frame scores, (FG1 = frame <3, FG2 = frame 3-4, FG3 = frame 4-5, FG4 = frame 5-6, FG5 = frame >6).

[c] Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each frame size classification.

[def] Means within the same row with different superscripts differ (P< .05).

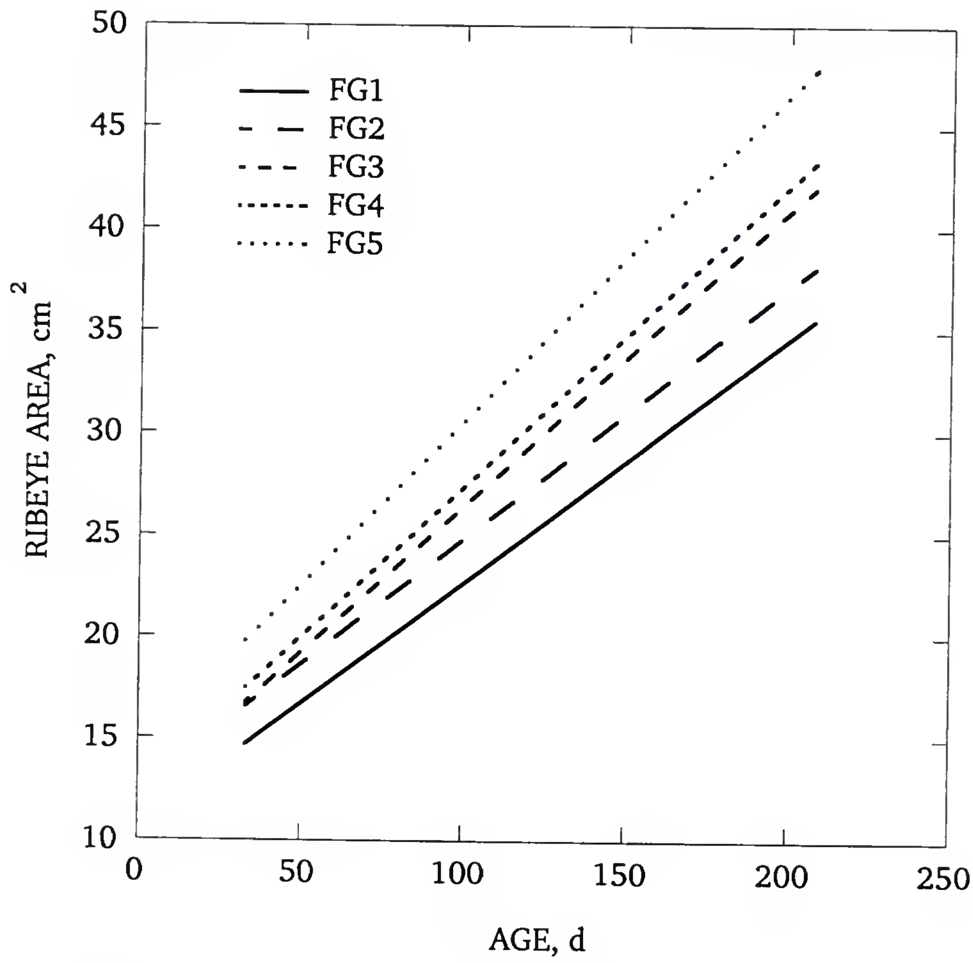

Figure 3-10. Preweaning ribeye area growth of steers among frame size classifications. Equations are as follows: FG1, ribeye area=10.72 + age(.119); FG2, ribeye area= 12.50 + age(.123); FG3, ribeye area=11.97 + age(.145); FG4, ribeye area=12.60 + age(.148); FG5, ribeye area=14.50 + age(.161).

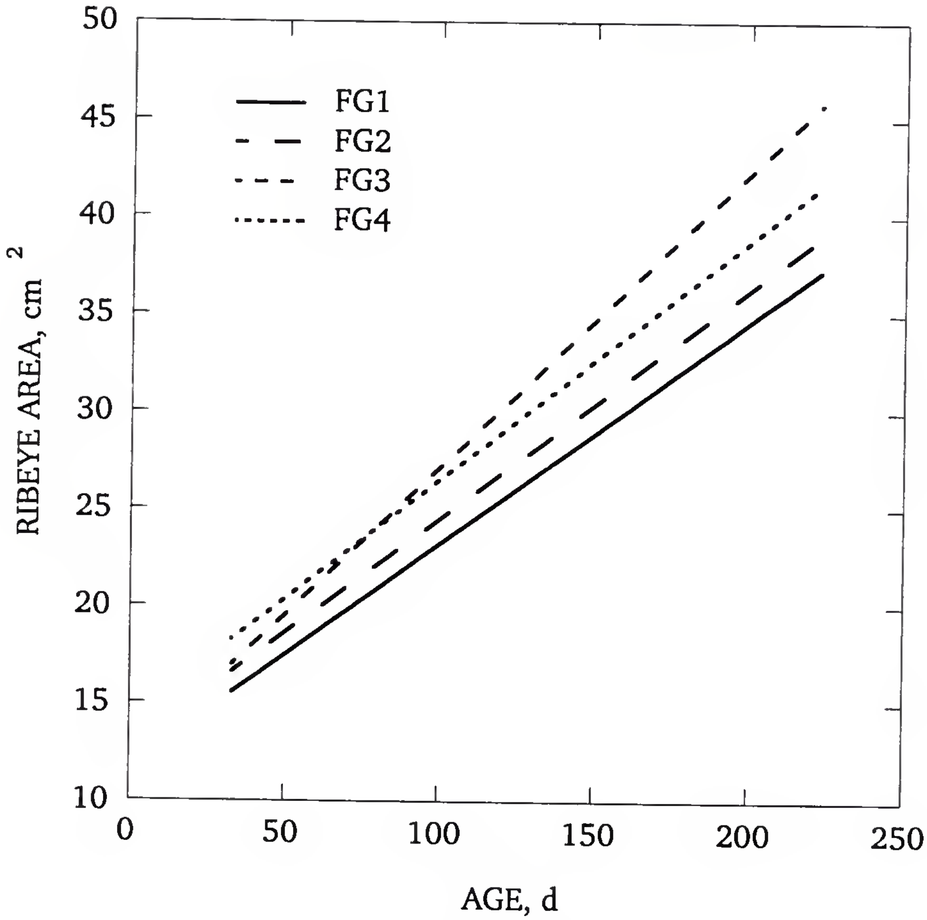

Figure 3-11. Preweaning ribeye area growth of heifers among frame size classification. Equations are as follows: FG1, ribeye area=11.56 + age(.114); FG2, ribeye area= 12.70 + age(.118); FG3, ribeye area=11.97 + age(.152); FG4, ribeye area=14.20 + age(123).

TABLE 3-9. REGRESSION COEFFICIENTS BY FRAME SIZE CLASSIFICATION FOR RIBEYE AREA/45.4 KG LIVE WEIGHT CHANGES WITH AGE IN STEERS AND HEIFERS.

Regression[a]	Frame size classification[b]					RMSE[c]
	FG1	FG2	FG3	FG4	FG5	
Preweaning						
Steers, n	11	22	35	23	8	
linear	-.0198	-.0168	-.0197	-.0181	-.0193	.012
quadratic	.00006	.00004	-.00002	-.00002	.000003	.0003
Heifers, n	35	36	24	2	N/A	
linear	-.0220[d]	-.0235[d]	-.0163[e]	-.0130[de]	N/A	.009
quadratic	.00009	.00013	.00005	-.00003	N/A	.0001
Postweaning						
Steers, n	3	15	20	13	5	
linear	-.0084	-.0040	-.0011	-.0045	-.0043	.011
quadratic	.00008	-.00010	-.00012	-.00006	-.00015	.0003

a Indicates the linear and quadratic regressions ultrasound ribeye area/45.4 kg live weight on age.

b Frame size calculated by the Beef Improvment Federation method where smaller numbers equate to smaller frame scores (FG1 = frame <3, FG2 = frame 3-4, FG3 = frame 4-5, FG4 = frame 5-6, FG5 = frame >6).

c Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each frame size classification.

de Means within the same row with different superscripts differ (P<.05).

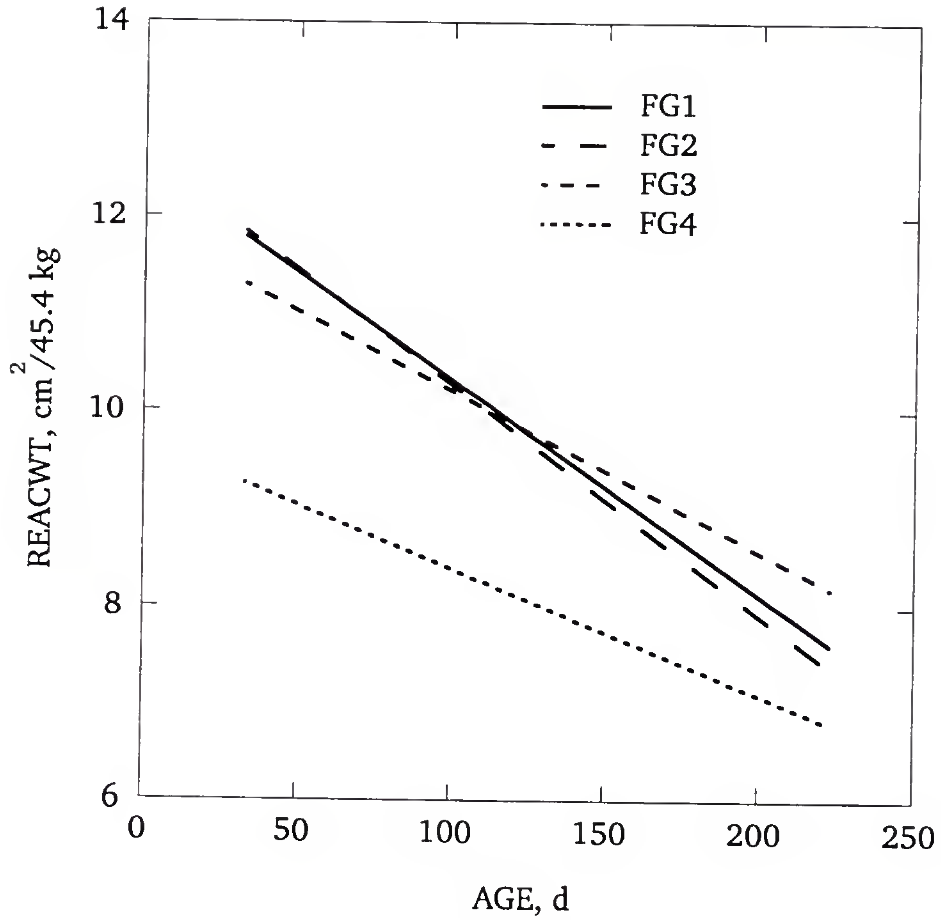

Figure 3-12. Preweaning change of ribeye area / 45.4 kg live weight in heifers, by frame size classification. Equations are as follows: FG1, REACWT=12.52 - age(.022); FG2, REACWT=12.63 - age(.024); FG3, REACWT=11.84 - age(.016); FG4, REACWT=9.69 - age(.013).

FG2 heifers. Ribeye area on a relative body weight basis, REACWT, may be a useful variable for evaluating ribeye area in cattle of various frame sizes.

Fat thickness changes did not differ ($P>.05$) among frame size groups (Table 3-10). Preweaning fat thickness measurement was relatively constant for both steers and heifers (Table 3-2). Postweaning fat deposition in steers was rapid (.0029 to .0055 cm/d) because they were on a high energy feedlot diet.

Frame size appears to be an important factor affecting preweaning weight gain and growth of ribeye. Larger frame cattle grow at a more rapid rate than smaller frame cattle. Some of this preweaning weight gain appears to come from an increase in muscle (ribeye area). Growth curves for ribeye area and weight gain are similar. Postweaning, frame size appears to be unimportant in describing the differences in growth patterns of steers when slaughtered at constant levels of fatness. The variable REACWT was not different among frame size groups, and therefore may be an appropriate variable to use to evaluate ribeye area measurements in cattle of various frame sizes.

Breed Group

The linear relationship of weight on age for steers was different ($P<.05$) among breed groups (Table 3-11). The linear regression coefficients for BG1 and BG5 were similar ($P>.05$), and were smaller ($P<.05$) than coefficients from BG2, BG3, and BG4. This suggests that the two groups that are partially composed of straightbred cattle, BG1 (81% to 100% Angus) and BG5 (81% to 100%

TABLE 3-10. REGRESSION COEFFICIENTS BY FRAME SIZE CLASSIFICATION FOR FAT THICKNESS CHANGES WITH AGE IN STEERS AND HEIFERS.

Regression[a]	Frame size classification[b] FG1	FG2	FG3	FG4	FG5	RMSE[c]
Preweaning						
Steers, n	11	22	35	23	8	
linear	.0006	.0007	.0006	.0005	.0005	.0005
quadratic	.000002	.000001	.000002	.000001	.000004	.00001
Heifers, n	35	36	24	2	N/A	
linear	.0007	.0007	.0009	.0008	N/A	.0005
quadratic	.000002	.000002	.000003	.000008	N/A	.000008
Postweaning						
Steers, n	3	15	20	13	5	
linear	.0055	.0038	.0039	.0038	.0029	.001
quadratic	-.0000002	.00003	.00003	.000006	.000007	.00003

[a] Indicates the linear and quadratic regressions of ultrasound fat thickness changes on age.

[b] Frame size calculated by the Beef Improvment Federation method where smaller numbers equate to smaller frame scores (FG1 = frame <3, FG2 = frame 3-4, FG3 = frame 4-5, FG4 = frame 5-6, FG5 = frame >6).

[c] Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each frame size classification.

TABLE 3-11. REGRESSION COEFFICIENTS BY BREED GROUP FOR WEIGHT CHANGES WITH AGE IN STEERS AND HEIFERS.

	Breed group[b]					
Regression[a]	1	2	3	4	5	RMSE[c]
Preweaning						
Steers, n	20	17	25	22	15	
linear	.8871[d]	1.0095[e]	1.0599[e]	1.0256[e]	.8812[d]	.123
quadratic	.0011[de]	.0016[e]	.0012[de]	.0006[d]	-.0018[f]	.001
Heifers, n	28	14	25	19	11	
linear	.8259[d]	.9706[e]	.9265[ef]	.9247[ef]	.8679[df]	.120
quadratic	.0012[d]	.0016[d]	.0015[d]	.0002[e]	-.0013[f]	.001
Postweaning						
Steers, n	7	12	16	15	6	
linear	1.5881	1.5619	1.5750	1.4904	1.2983	.230
quadratic	.0100[d]	.0091[d]	.0054[e]	.0017[f]	-.0023[fg]	.005

[a] Indicates the linear and quadratic regressions of weight on age.

[b] Breed groups were from known Brahman and Angus matings and were segregated into groups based on the following percentages of Angus breeding; 1 = 100 - 81 % Angus, 2 = 80 - 61 % Angus, 3 = 60 - 41 % Angus, 4 = 40 - 21 % Angus, and 5 = 20 - 0 % Angus.

[c] Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each breed group.

[defg] Means within the same row with different superscripts differ (P<.05).

Brahman), had slower ($P<.05$) weight gain during the preweaning phase than BG2, BG3, and BG4. Table 3-11 shows the quadratic regression coefficients for steers are different ($P<.05$) among breed groups and the quadratic equations are plotted graphically in Figure 3-13. The coefficient for BG2 is larger ($P<.05$) than the coefficient for BG4, while BG1 and BG3 are intermediate and not significantly different from BG2 and BG4. The coefficient for BG5 is negative and smaller ($P<.05$) than all other breed groups and therefore the plotted line from the equation takes a different shape (Figure 3-13). Calves from BG5 started out at lighter weights than the other breed group; however, these steers grew at a faster rate during the first 100 d of life. After this point, growth appeared to slow somewhat for the BG5 calves and they eventually had the lightest weights at weaning.

Preweaning heifer data, by breed group, showed trends very similar to steers. The linear coefficient for preweaning weight gain for BG1 was significantly smaller than coefficients for BG2, BG3, and BG4, while the coefficient for BG5 was smaller ($P<.05$) than the coefficient for BG2. Quadratic equations for heifers are different among breed groups. The coefficients show a decreasing trend with increasing Brahman breeding. Coefficients from BG1, BG2, and BG3 are similar ($P>.05$) and larger ($P<.05$) than coefficients from BG4, which were larger ($P<.05$) than coefficients from BG5. These curves are plotted in Figure 3-14. The curve for the group with the highest percentage Brahman breeding (BG5) shows a very slight leveling at about 100 d of age, whereas the

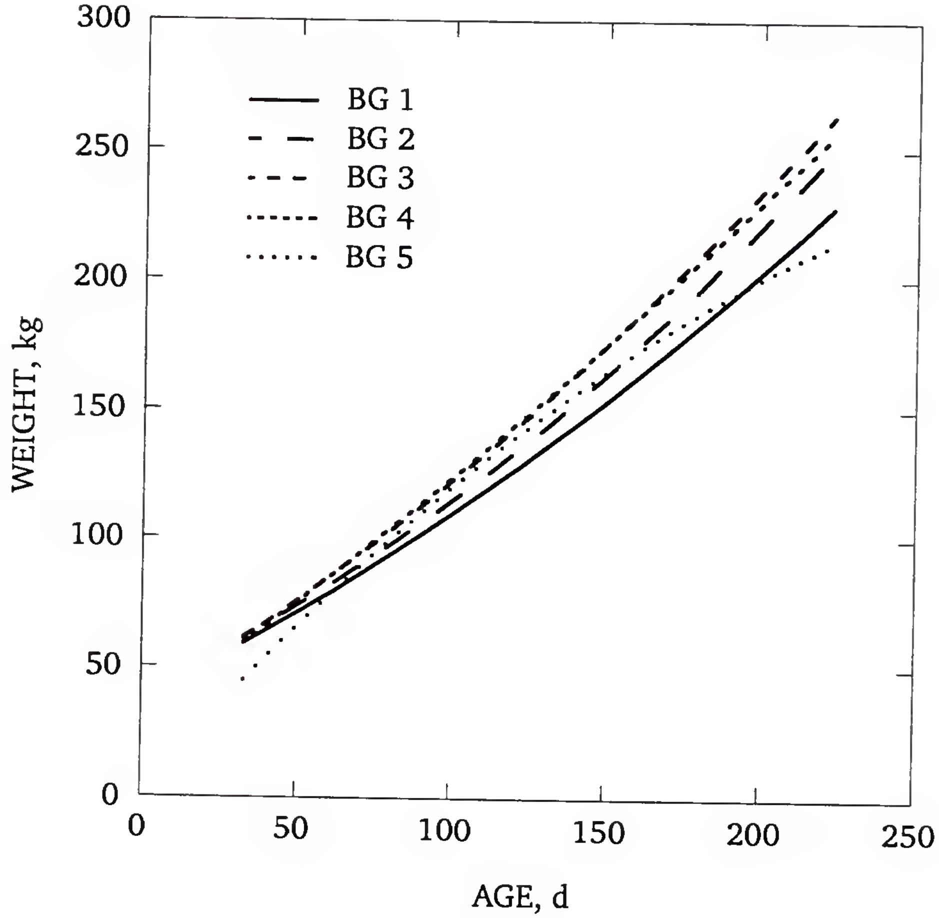

Figure 3-13. Preweaning weight gain of steers by breed group (BG). Equations are as follows: BG 1, weight=37.85 + age(.606) + age^2(.001); BG 2, weight=40.71 + age(.577) + age^2(.002); BG3, weight=34.73 + age(.752) + age^2(.001); BG4, weight=29.64 + age(.873) + age^2(.0006); BG5, weight=2.03 + age(1.363) - age^2 (.002).

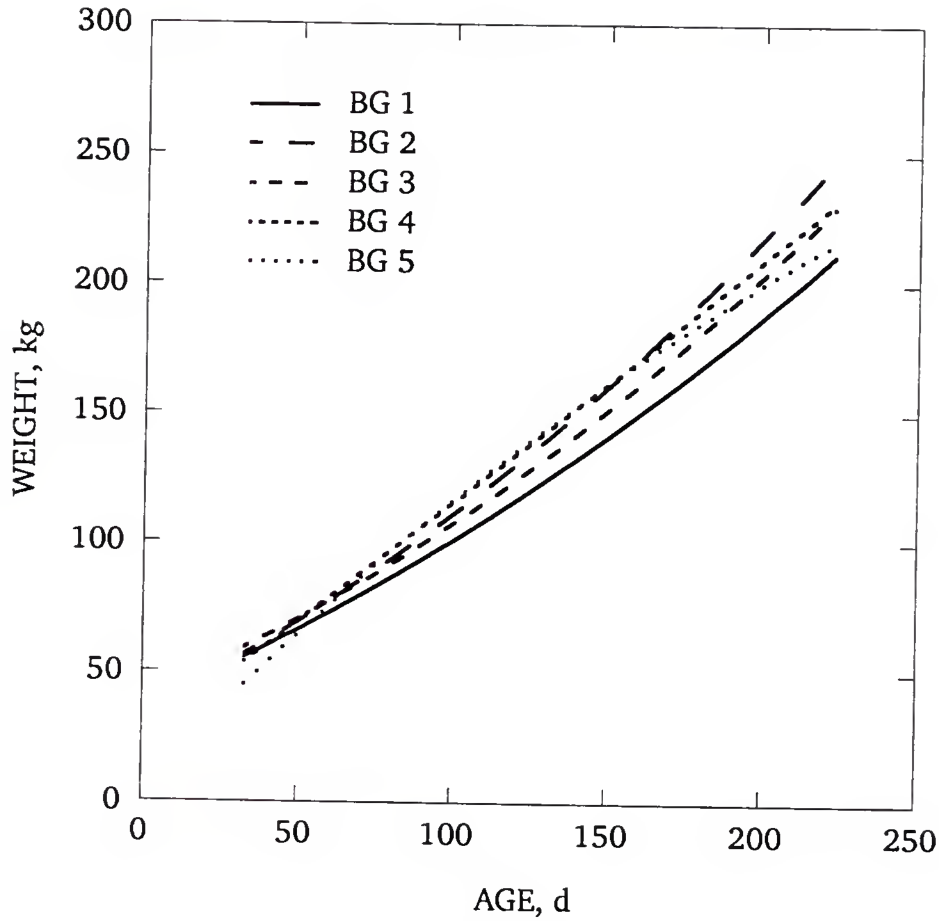

Figure 3-14. Preweaning weight gain of heifers by breed group (BG). Equations are as follows: BG1, weight=37.44 + age(.512) + age^2(.001); BG2, weight=35.28 + age(.598) + age^2(.002); BG3, weight=40.67 + age (.514) + age^2(.0002); BG4, weight=24.21 + age(.893) + age^2(.0002); BG5, weight=5.95 + age(123) - age^2(.001).

curves for heifers in BG1, BG2, and BG3 all showed an upward trend during this age period. Heifers from BG4 had a weight growth curve that was almost linear during the preweaning phase.

Table 3-11 also shows growth coefficients for steers postweaning. Linear coefficients for steers were not significant; however, there was a tendency ($P=.12$) for the groups with lower percentage of Brahman breeding (BG1, BG2, and BG3) to have a faster rate of growth during the postweaning phase than BG5. The quadratic coefficients were different among breed groups of steers and the equations are plotted in Figure 3-15. The intercepts of the curves are quite different, with the higher percentage Angus calves weighing the most at weaning and the higher percentage Brahman calves weighing the least. There was a backgrounding period of 75 d after weaning, before the steers were placed in the feedlot, during which time steers from BG1 and BG2 lost weight. Table 3-12 gives the regression coefficients for ribeye area changes with age among breed groups. During the preweaning phase, steers and heifers from BG1 had the slowest ($P<.05$) linear growth of ribeye area. The other four breed groups were not statistically different; however, there appeared to be an increasing trend with increasing percentage Brahman breeding. Figure 3-16 depicts the preweaning linear trends of ribeye area growth in steers. Breed groups 2 through 4 all show a similar ($P>.05$) relationship between ribeye area and age, while BG1 shows a significantly slower ($P<.05$) rate of ribeye area growth. Figure 3-17 shows the quadratic equations for heifer ribeye area growth by breed group, and again the

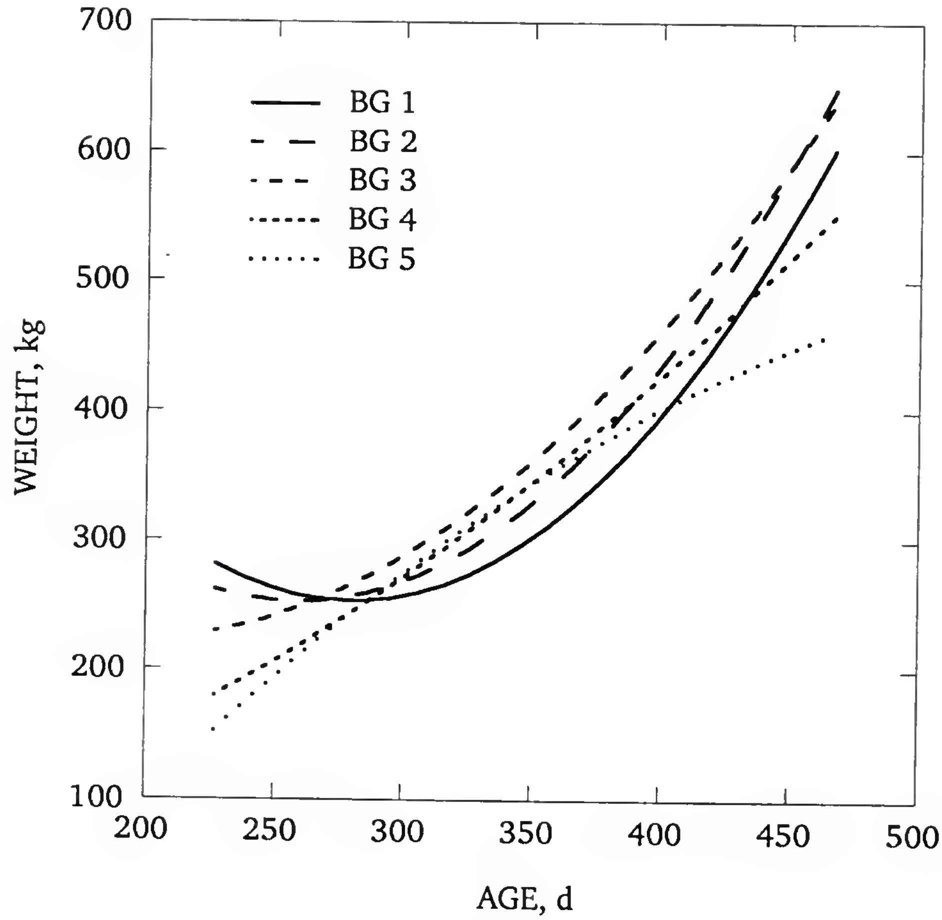

Figure 3-15. Postweaning weight gain of steers by breed group (BG). Equations are as follows: BG1, weight=1039.2 - age(5.61) + age^2 (.010); BG2, weight=865.2 - age(4.73) + age^2(.009); BG3, weight =416.4 - age(2.05) + age^2(.005); BG4, weight=11.9 + age(.344) + age^2(.002); BG5, weight=-380.3 + age(2.86) - age^2(.002).

TABLE 3-12. REGRESSION COEFFICIENTS BY BREED GROUP FOR RIBEYE AREA CHANGES WITH AGE IN STEERS AND HEIFERS.

	Breed group[b]					
Regression[a]	1	2	3	4	5	RMSE[c]
Preweaning						
Steers, n	20	17	25	22	15	
linear	.1077[d]	.1401[e]	.1470[e]	.1461[e]	.1550[e]	.036
quadratic	-.00016	-.00026	-.00027	-.00034	-.00054	.0007
Heifers, n	28	14	25	19	11	
linear	.1021[d]	.1444[e]	.1263[e]	.1339[e]	.1411[e]	.038
quadratic	.00007[d]	.00009[d]	.00006[d]	-.0002[e]	-.0004[e]	.0004
Postweaning						
Steers, n	7	12	16	15	6	
linear	.2723	.2604	.2246	.2366	.2106	.054
quadratic	.00111	.00004	.00033	.00068	.00067	.001

[a] Indicates the linear and quadratic regressions of ultrasound ribeye area on age.
[b] Breed groups were from known Brahman and Angus matings and were segregated into groups based on the following percentages of Angus breeding; 1 = 100 - 81 % Angus, 2 = 80 - 61 % Angus, 3 = 60 - 41 % Angus, 4 = 40 - 21 % Angus, and 5 = 20 - 0 % Angus.
[c] Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each breed group.
[de] Means within the same row with different superscripts differ (P<.05).

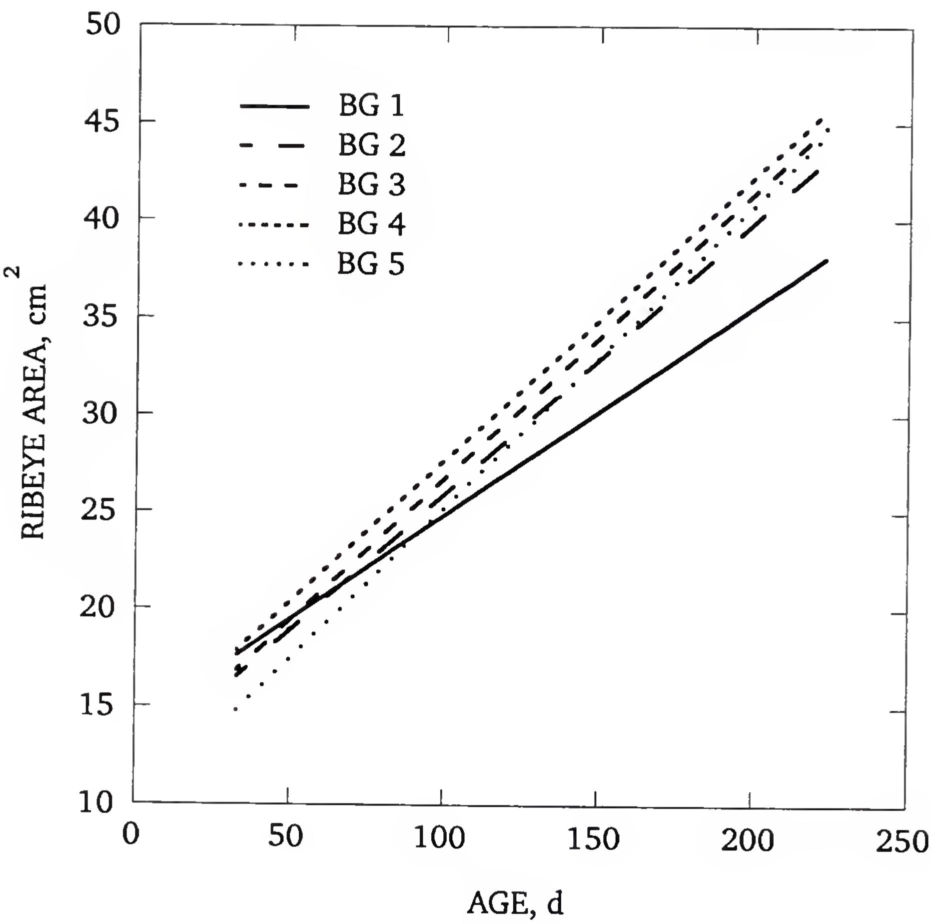

Figure 3-16. Preweaning ribeye area growth of steers among breed groups (BG). Equations are as follows: BG1 , ribeye area= 14.91 + age(.108); BG2, ribeye area=11.91 + age(.140); BG3, ribeye area =12.04 + age(.147); BG4, ribeye area=13.07 + age(.146); BG5, ribeye area=9.66 + age(.156).

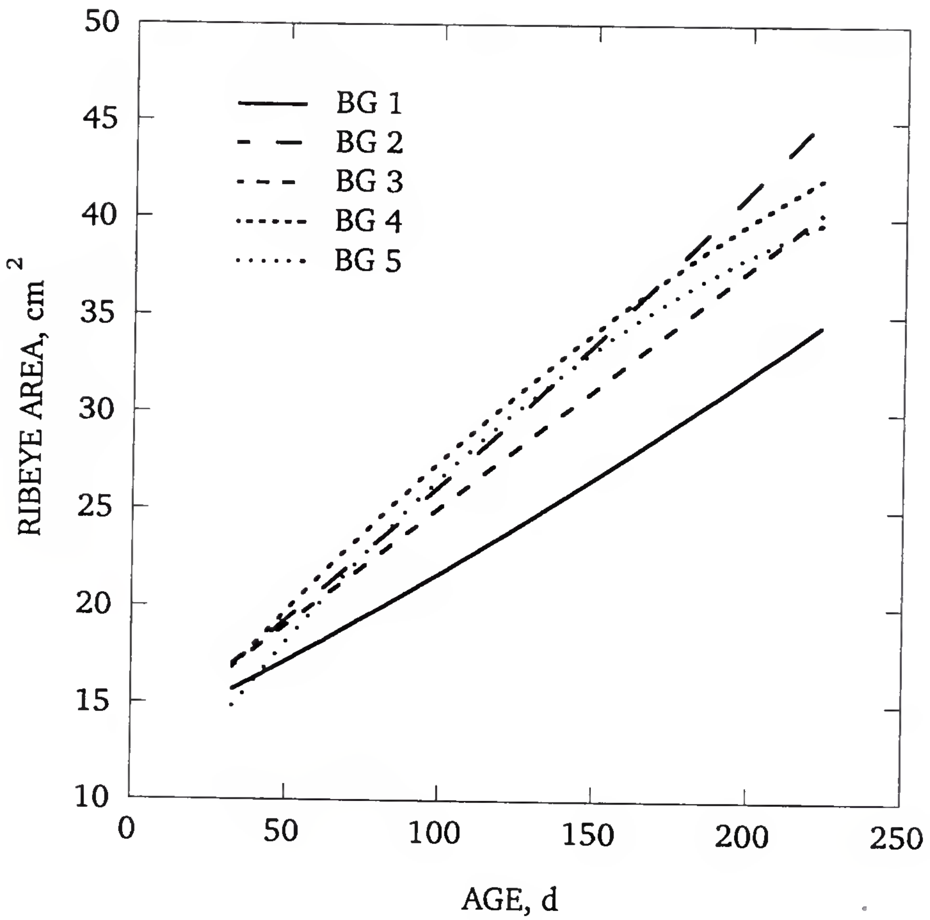

Figure 3-17. Preweaning ribeye area growth of heifers by breed group (BG). Equations are as follows: BG1, ribeye area=13.00 +age(.080) + age^2(.00007); BG2, ribeye area=12.80 + age (.125) + age^2(.00009); BG3, ribeye area=12.90 + age(.122) + age^2(.000006); BG4, ribeye area=10.87 + age(.188) - age^2(.0002); BG5, ribeye area=7.86 + age(.224) - age^2(.0004).

group with the highest percentage Angus breeding (BG1) producing a dissimilar ribeye area growth curve. Quadratic coefficients from BG4 and BG5 are negative and smaller ($P<.05$) than coefficients from the other three breed groups. As was the case with weight (Figure 3-14), curves from BG5 showed a leveling around 100 d of age while curves from the other groups showed an upturn. Postweaning, there was a tendancy ($P = .13$) for steers with a greater percentage of Brahman breeding to have slower ribeye area growth.

Table 3-13 shows regression coefficients by breed group for REACWT. As with the frame size analysis, no differences were noted among breed groups during the preweaning phase. Differences among breed groups were significant during the postweaning phase. The quadratic regression of REACWT on age in steers is graphically displayed in Figure 3-18. Coefficients from BG1, BG2, and BG3 were not different ($P>.05$); however, coefficients for REACWT from BG2 were more negative ($P<.05$) that those from BG4. The quadratic curve for BG5 takes a drastically different shape than curves from BG1, BG2, and BG3. The reason for this difference is unknown.

Table 3-14 provides regression coefficients by breed group for fat thickness changes with increasing age. As discussed in Table 3-2, there was very little change in fatness during the preweaning phase. Figure 3-19 shows the range of fat thickness change during the preweaning phase only spanned about .2 cm, and therefore, any breed group differences were probably of little practical significance. However, it should be noted that quadratic coefficients of heifers

TABLE 3-13. REGRESSION COEFFICIENTS BY BREED GROUP FOR RIBEYE AREA/45.4 KG LIVE WEIGHT CHANGES WITH AGE IN STEERS AND HEIFERS.

Regression[a]	Breed group[b] 1	2	3	4	5	RMSE[c]
<u>Preweaning</u>						
Steers, n	20	17	25	22	15	
linear	-.0231	-.0189	-.0182	-.0176	-.0148	.011
quadratic	.00002	-.00003	-.000006	.00002	.00003	.0003
Heifers, n	28	14	25	19	11	
linear	-.0218	-.0212	-.0213	-.0223	-.0156	.010
quadratic	.00013	.00012	.00007	.00010	.00002	.0001
<u>Postweaning</u>						
Steers, n	7	12	16	15	6	
linear	-.0008	.0012	-.0040	-.0074	-.0033	.011
quadratic	-.00013[de]	-.00027[d]	-.00014[de]	-.0000008[ef]	.0002[f]	.0003

a Indicates the linear and quadratic regressions of ultrasound ribeye area/45.4 kg live weight on age.

b Breed groups were from known Brahman and Angus matings and were segregated into groups based on the following percentages of Angus breeding; 1 = 100 - 81 % Angus, 2 = 80 - 61 % Angus, 3 = 60 - 41 % Angus, 4 = 40 - 21 % Angus, and 5 = 20 - 0 % Angus.

c Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each breed group.

def Means within the same row with different superscripts differ (P<.05).

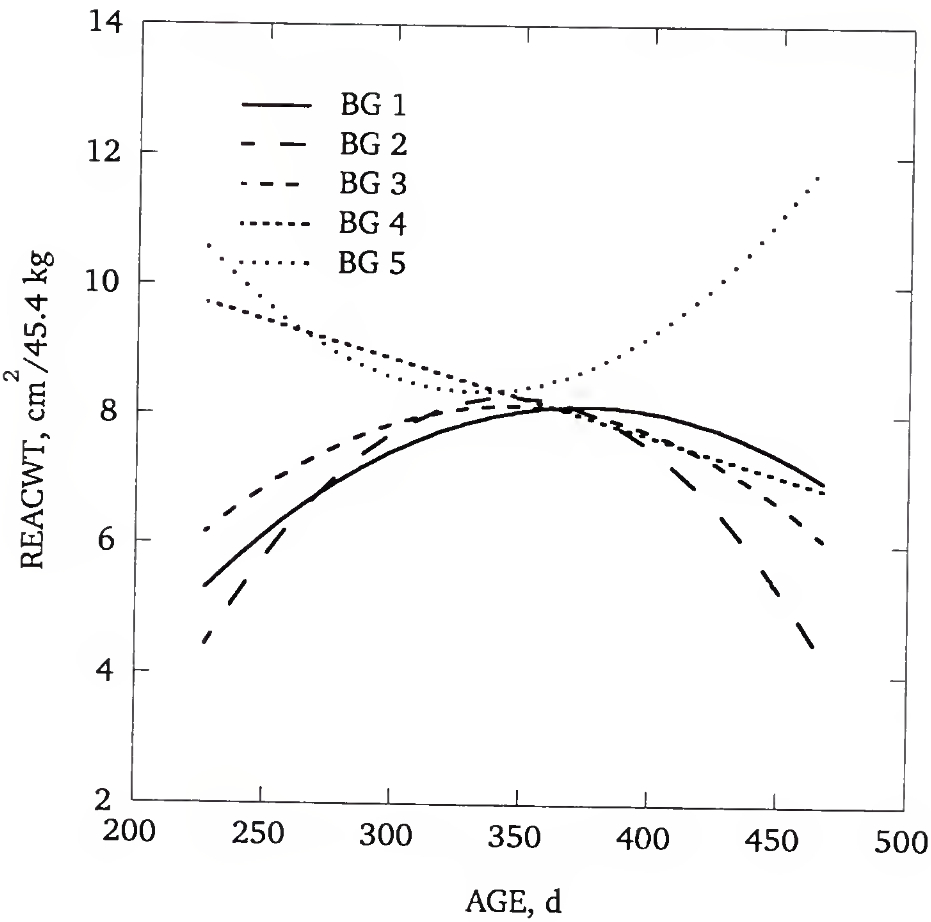

Figure 3-19. Postweaning change of ribeye area / 45.4 kg live weight of steers by breed group (BG). Equations are as follows: BG1, REACWT=-10.28 + age(.099) - age^2(.0001); BG2, REACWT=-24.22 + age(.188) - age^2(.0003); BG3, REACWT= -8.61 + age(.097) - age^2(.0001); BG4, REACWT=12.34 - age (.011) - age^2(.000001); BG5, REACWT=30.21 - age(.131) + age^2(.0020).

TABLE 3-14. REGRESSION COEFFICIENTS BY BREED GROUP FOR FAT THICKNESS CHANGES WITH AGE IN STEERS AND HEIFERS.

	Breed group[b]					
Regression[a]	1	2	3	4	5	RMSE[c]
<u>Preweaning</u>						
Steers, n	20	17	25	22	15	
linear	.0005	.0006	.0008	.0004	.0007	.0005
quadratic	.000004	.000002	-.0000002	.000003	.000001	.00001
Heifers, n	28	14	25	19	11	
linear	.0006	.0009	.0008	.0007	.0009	.0005
quadratic	.0000009[d]	.000007[e]	.000002[d]	.000004[de]	.0000009[d]	.000008
<u>Postweaning</u>						
Steers, n	7	12	16	15	6	
linear	.0044[d]	.0044[d]	.0041[d]	.0034[de]	.0023[e]	.001
quadratic	.00004[d]	.00003[d]	.00002[d]	.000004[e]	.000005[e]	.00003

[a] Indicates the linear and quadratic regressions of ultrasound fat thickness on age.

[b] Breed groups were from known Brahman and Angus matings and were segregated into groups based on the following percentages of Angus breeding; 1 = 100 - 81 % Angus, 2 = 80 - 61 % Angus, 3 = 60 - 41 % Angus, 4 = 40 - 21 % Angus, and 5 = 20 - 0 % Angus.

[c] Standard errors may be calculated by RMSE / $\sqrt{n}$, where RMSE = root mean square error and n = the number of steers or heifers in each breed group.

[de] Means within the same row with different superscripts differ (P<.05).

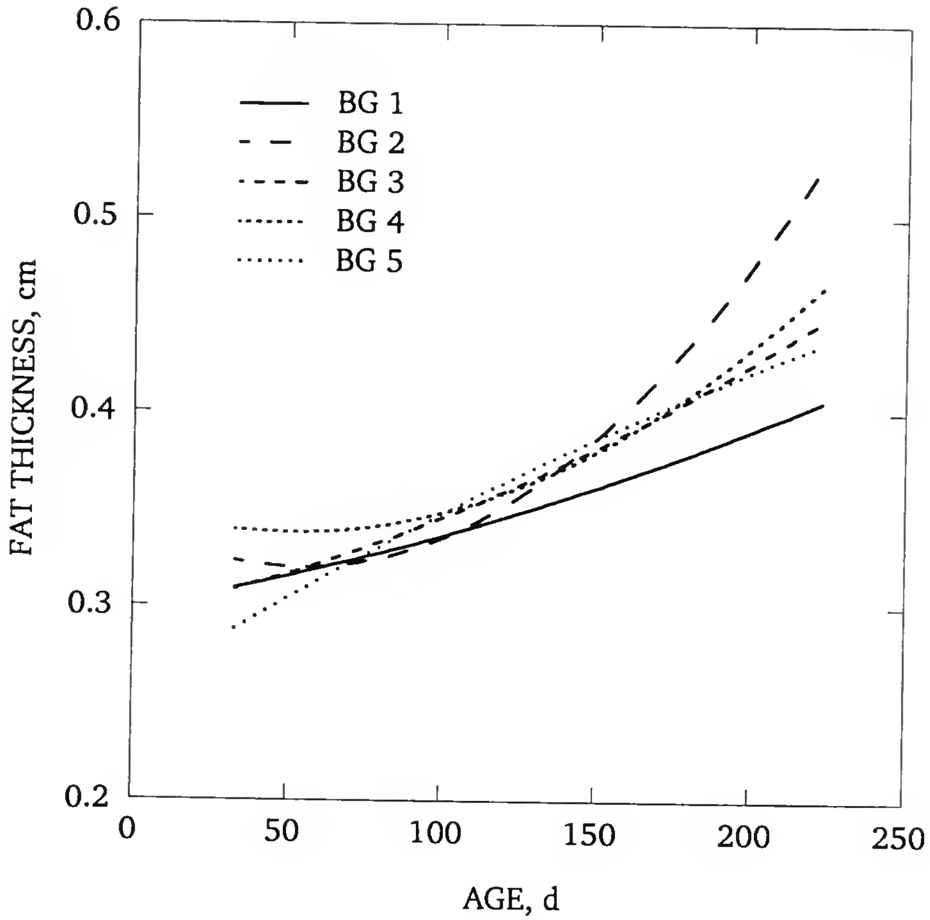

Figure 3-19. Preweaning fat thickness growth of heifers by breed group (BG). Equations are as follows: BG 1, fat thickness=.299 +age(.0003) + age^2(.000001); BG2, fat thickness=.342 - age (.0008) + age^2(.00001); BG3, fat thickness=.295 + age(.0003) + age^2(.000004); BG4, fat thickness=.349 - age(.0005) + age^2 (.000004); BG5, fat thickness=.256 + age(.001) - age^2(.000001).

differed among breed groups. Coefficients for BG2 were different ($P<.05$) from coefficients for BG1, BG3, and BG5. The curves for the equations are plotted in Figure 3-19.

Postweaning linear coefficients for fat thickness growth for steers in BG5 are significantly lower than coefficients for steers in BG1, BG2, and BG3. The quadratic coefficients show much the same trend and the curves from these equations are plotted in Figure 3-20. These curves are very similar to the postweaning weight change curves and may help explain why weight decreased for about 75 d postweaning in BG1 and BG2 while increasing steadily in BG4 and BG5. It is postulated that higher percentage Angus calves may have had greater appatite and therefore had more condition at weaning than calves with higher percentage Brahman breeding. Hargrove (1962) reported that appatite was lower in calves from predominantly Brahman breeding than for calves from Bos taurus breeding. During the stress of weaning, calves from BG1 and BG2 lost weight, most probably in the form of fat. When the calves were placed in the feedlot, at about 300 d of age, fat deposition then increased dramatically. Additionally, the higher percentage Brahman calves, BG4 and BG5, were born later in the calving season and therefore were weaned later than the other breed groups. This resulted in less time being spent in the backgrounding phase for BG4 and BG5 when compared with the other breed groups.

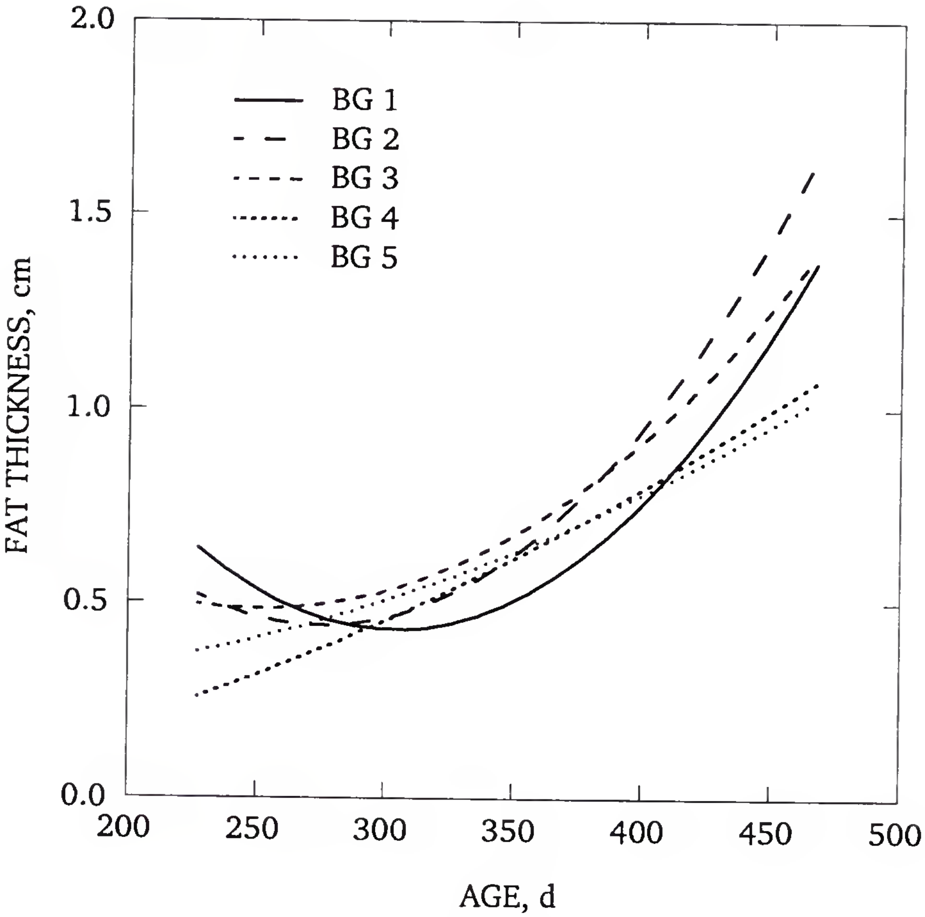

Figure 3-20. Postweaning fat thickness growth of steers by breed group (BG). Equations are as follows: BG1, fat thickness= $3.71 - \text{age}(.022) + \text{age}^2(.00004)$; BG2, fat thickness= $2.95 - \text{age}(.018) + \text{age}^2(.00003)$; BG3, fat thickness= $1.75 - \text{age}(.010) + \text{age}^2(.00002)$; BG4, fat thickness= $-.077 + \text{age}(.0005) + \text{age}^2(.000004)$; BG5, fat thickness= $.316 - \text{age}(.001) + \text{age}^2(.000005)$.

Implications

This study provides a unique look at cattle growth from a very young age to slaughter. Before weaning, steers increase in weight and ribeye area at a faster rate than heifers, and ribeye area on a relative body weight basis (REACWT) declines at a faster rate in heifers than in steers. When evaluating growth preweaning, cattle of different sex conditions should be evaluated separately. Frame size plays a role in preweaning growth, with large frame cattle showing faster weight gain and ribeye area growth than small frame cattle; however, REACWT was not different among frame size groups. Cattle of predominantly Angus breeding (81% to 100%) tended to have slower weight gain and ribeye area growth to weaning than did breed groups comprised of 20% to 100% Brahman breeding. Breed groups were not different for REACWT. This suggests that for evaluating ribeye area in cattle up to weaning, REACWT may be the best method across various frame sizes and breed groups. Feedlot steer weight gain and ribeye area growth were not different among frame size groups or breed groups. Fat thickness changes during the feedlot period for steers of predominantly Angus breeding were very different than the other four breed groups, thus suggesting a breed effect exists for rate of fat deposition.

CHAPTER 4

SUMMARY AND CONCLUSIONS

This manuscript focused on the usefulness of ribeye area as a measurement of muscularity in beef cattle. The first study was designed to evaluate the relationship between ribeye area and cutability in a subset of the present cattle population that represents a relatively narrow range of carcass weight and fat thickness. Results indicate that ribeye area was moderately correlated with carcass cutability end points and ribeye area was as valid as any other carcass measurements evaluated for predicting carcass cutability. However, because carcasses in this study were chosen to represent a relatively narrow range of carcass weight and fat thickness, only 12% to 20% of the variation in cutability could be explained by ribeye area alone. The variables from the USDA yield grade equations explained from 28% to 38% of the variation in carcass cutability. There was a tendency for carcasses classified as "above average" for ribeye area to have greater cutability than those classified as "below average" for cutability. Individual muscle and bone measurements were included in multiple regression analysis and were found to be useful predictors of cutability when combined with standard carcass measurements (R^2 = .56 to .65). It was concluded from the first study that prediction equations designed to predict cutability of "typical" beef

carcasses should include ribeye area along with other carcass measurements. If feasible, major muscle and/or bone weights should be used as they greatly enhance the predictive value of regression equations designed to predict carcass cutability.

The second part of this study addressed cattle growth from a very young age to slaughter. Serial measurements of weight, ribeye area and fat thickness measured ultrasonically, and ribeye area/45.4 kg live weight (REACWT) were regressed on age and growth coefficients were evaluated. Before weaning, steers increase in weight and ribeye area at a faster rate than heifers, and ribeye area on a relative body weight basis (REACWT) declines at a faster rate in heifers than in steers. When evaluating growth preweaning, cattle of different sex conditions should be evaluated separately. Frame size plays a role in preweaning growth, with large frame cattle showing faster weight gain and ribeye area growth than small frame cattle; however, REACWT was not different among frame size groups. Postweaning, frame size groups were not different for growth patterns of weight, ribeye area, REACWT and fat thickness. Cattle of predominantly Angus breeding (81% to 100 %) tended to have slower weight gain and ribeye area growth to weaning than did breed groups comprised of 20% to 100% Brahman breeding. Breed groups were not different for REACWT. Feedlot steer weight gain and ribeye area growth were not different among frame size groups or breed groups. Fat thickness changes during the feedlot period for steers of predominantly Angus breeding were very different than the other four breed

groups. Breed groups with 60% to 100% Angus breeding lost fat during a 75 d backgrounding period, while steers with 40% to 100% Brahman breeding gained fat throughout the backgrounding and feedlot phase, thus suggesting a breed effect for the rate of fat deposition. This may be more easily explained the the fact that the higher percentage Brahman calves spent less time in the backgrounding phase. This phenomena needs further study.

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BIOGRAPHICAL SKETCH

Randall Dale Huffman was born in Auburn, Alabama, September 11, 1964. He received his high school diploma from Auburn High School, Auburn, Alabama, in June, 1982. In the fall of 1982 he enrolled at Auburn University where he majored in Animal and Dairy Sciences and, in the spring of 1986, he received the degree of Bachelor of Science. In August, 1986, he accepted a graduate assistantship from the Department of Animal Science, University of Florida and, on December 17, 1988 he received the degree of Master of Science. On that same date, he was wed to Miss Laura Ann Lockard, of Auburn, Alabama. In January, 1989, he began pursuit of the degree of Doctor of Philosophy, in the field of meat science, in the Department of Animal Science, University of Florida.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Roger L. West, Chair
Professor of Animal Science

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D. Dwain Johnson, Cochair
Associate Professor of Animal Science

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